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MOBILITY RESEARCH ON SMALL HIGH-MOBILITY VEHICLES

Project Report by

Organic and Associated Terrain Research Unit
McMaster University
Hamilton, Ontario

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MOBILITY RESEARCH ON SMALL HIGH-MOBILITY VEHICLES

INTRODUCTION

This report is concerned with a comparison of two vehicles, both amphibious and producing exceedingly low ground pressure. Vehicle characteristics and data sheets are included (Appendix 1). No further reference is made to the design specifications nor to the principles on which each vehicle operates. Vehicle "A" is shown in Figs. 1 and 2, vehicle "B" in Figs. 3 and 4.

In this mobility comparison, appraisal of design is limited to those features affecting terrain/vehicle relations as reflected in mobility performance, and is not intended to assess other engineering design features.

All testing was done under off-road conditions, and in organic as well as mineral terrain. It was required that the vehicles be tested in the various kinds of organic terrain usually regarded as critical as regards their bearing capacity. Because of time limitations, five types of organic terrain were selected, which together presented those conditions now internationally recognized as critical in trafficability studies.

Appraisal of performance in open water and over rugged granitic outcrop landscape was also required.

It was requested that OATRU select and record the nature of the terrain for purposes of reference, standardization, and future comparison. Accordingly, during the early part of the summer, a test plan was developed. The test locations, about 20 miles north of Parry Sound, Ontario, were mapped, and the terrain conditions evaluated qualitatively and quantitatively.

OATRU implemented and directed the test program. Modifications were made in consultation with vehicle owners and the approval of the Project Officer.

In order that the results could be assessed in relation to airphoto examination, the preliminary study involved direct aerial inspection and production of aerial obliques of the terrain for future reference.

To convey descriptive values pictorially, documentation included an atlas of photographs, in addition to the text figures herewith, showing field conditions and vehicle response. An edited 16 mm. color film was also submitted with this report.

PLAN AND PROGRAM OF TESTS

TEST SITE

The maps and photographs in Appendix 2 contain information on routes, test sites, terrain types, vehicle hazards and obstacles, route deviations, and route profile.

Routes were marked as indicated on the maps — all markers on the lake side of the route were red, and those on alternative routes were yellow. The alternative routes were provided so that vehicles that failed to negotiate a chosen obstacle might be presented with a similar but less difficult obstacle.

Test lanes were marked with corner posts and guide-lines.

TYPES OF MUSKEG FOR TEST LANES

The areas chosen were considered critical and representative. They were designated test sites A, B, C, D, E and were of the following types, ranked in order of expected difficulty starting with the most difficult: G (wet amorphous granular peat covered with lily pads), FEI, DI, BFI, EI.

These types and those mentioned later (see "Terrain Description") are commonly recurring examples. The grouped letter symbols are described in the literature (1), and are known as vegetal cover classes, which seldom occur alone. When they are grouped in formulae to convey combined cover character, the tallest vegetal class covering most surface is placed on the left of the formula, the other classes following in order of descending size and extent of cover. If estimated cover for a given class symbol is less than 25 per cent, it is omitted. The formula thus stands for most of the cover within an arbitrarily pre-delineated area. A group (cover formula) never contains more than three classes, and frequently two suffice.

Cover formulae so derived are now in wide use (2, 3). Those referred to in this report and related ones occur commonly in Canada (4) and in many other countries in both northern and sourthern hemispheres. Their importance lies in the fact that they not only stand for structural properties (size, form, and texture) of the vegetal cover, but also indicate subsurface structural conditions in the underlying peat or fossilized organic medium.

The terrain types characterized by these cover formulae, when viewed from the air singly or in combination, are organized into patterns (5), two of which (dermatoid and stipploid) prescribe for these investigations.

The reader is directed to the photographs referred to in the section "Terrain Description and Significance" for pictorial reference to cover formulae.

TRIALS PROGRAM

The four tests that were planned for the various types of terrain in the five test sites A to E are described here, followed by test details for certain areas.

Trial 1 — Mobility

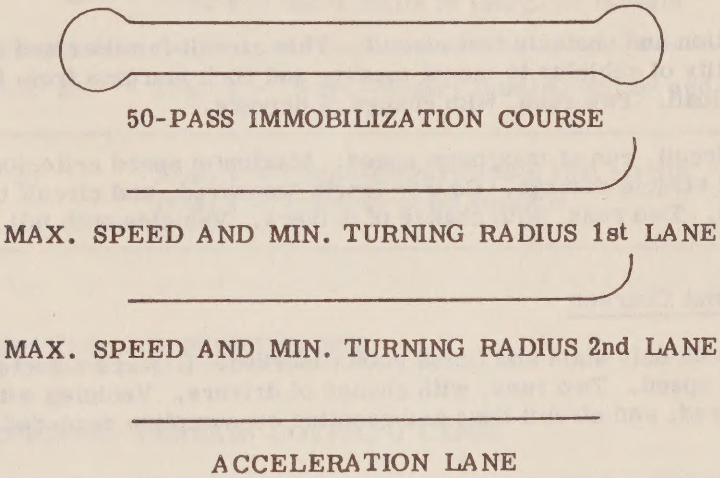
Test (a) Number of passes to immobilization, with usual cone penetrometer and subsidence measurements. Observation of points of high slippage during each pass, number of involuntary

decelerations during first pass, and time of first pass run or minimum speed. Performed with maximum payload. If immobilized during first pass, payload decreased sufficiently to make vehicle mobile.

Test (b) Maximum speed carrying full payload, or maximum speed at which vehicle was mobile, timed over a measured and staked 100 ft. course. Maximum speed criterion was driver comfort or available power. Two runs with change of drivers.

Test (c) Minimum turning radius at end of high-speed run. Driver to begin the turn at end stake of the 100 ft. speed run.

Test (d) Acceleration test. Minimum time to go 100 ft. from a standing start.



Layout of Test Lanes Required for Each Vehicle (length of lane 100 ft.)

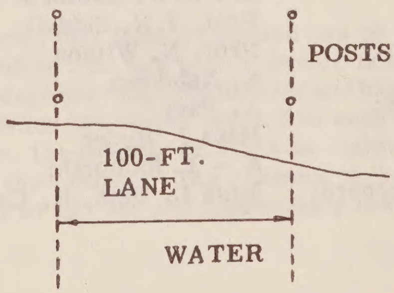
Trial 2 — Water Areas

Water test lane 100 ft. long, ends marked by two posts in line on shore. Depth greater than wading depth. Full payload carried.

Test (a) Check on floatability and steerability of vehicles by run out from shore and back.

Test (b) Maximum water speed. Vehicles timed over 100 ft. test lane. Two runs, with change of drivers.

Test (c) Vehicles tested for maneuverability and seaworthiness in maximum available wind and wave conditions.



Layout of Test Lane in Water

Trial 3 — Short Trails in Inorganic Terrain

Test (a) Speed tests. Two courses in terrain unlikely to damage vehicles, each about 200 to 300 yd. long, measured. Two runs, with change of drivers. Maximum speed criterion was driver safety or avoidance of vehicle damage. Speed determined by means of radios and stop watch. Vehicles ran course in succession, carrying full payload.

Test (b) Maneuverability and obstacle course. One course to include typical natural obstacles. Two runs, with change of drivers. Observers to take notes on each obstacle.

Trial 4 — Cross-Country Course

This course was a complete circuit of Dinner Lake, 1 to 1 1/2 miles long.

Test (a) Familiarization and obstacle test circuit. This circuit familiarized drivers with the course and tested ability of vehicles to mount muskeg and rock margins from free water. Vehicles with full payload. Two runs, with change of drivers.

Test (b) Speed test circuit, run at maximum speed. Maximum speed criterion was driver safety or avoidance of vehicle damage. Course length measured, and circuit time and gasoline consumption recorded. Two runs, with change of drivers. Vehicles with full payload.

Trial 5 — Point-to-Point Courses

Two courses set up, with only start and finish points marked. Drivers selected routes and travelled at maximum speed. Two runs, with change of drivers. Vehicles with full payload. Course lengths measured, and circuit time and gasoline consumption recorded.

OTHER OBSERVATIONS

Cone penetrometer and subsidence readings were obtained prior to and during vehicle tests, to determine changes in the terrain.

Sand-bags were used to vary the loads carried by the vehicles, and payloads were decided on in consultation with the vehicle owners. They were limited by stowage space, means of fastening the load securely, and considerations of balance. Equipment for accurate measurement of fuel consumption was attached as required.

RESPONSIBILITIES

Trials Officer:	Dr. N.W. Radforth
Deputy Trials Officer:	Prof. J.N. Siddall
Soil Instrumentation:	Prof. N. Wilson
Field Manager:	K. Ashdown
Assistant Field Manager:	A. Paul
Survey:	Miss J. Ryder
Drivers:	A — J. Radforth; B — R. Sumner
Photographers and Recorders:	Miss L. Usik, K. Cardwell, R. Menzies

TIME TABLE OF TESTS

	General Familiarization with Vehicles — 2 hours
MONDAY AUGUST 26	Trial 1 — Test lane tests in EI, FEI
TUESDAY AUGUST 27	Trial 1 — Test lane tests in G, BFI, DI
WEDNESDAY AUGUST 28	Trial 2 — Water trials Trial 3 — Short trails in inorganic terrain
THURSDAY AUGUST 29	Trial 4 — Cross-country familiarization and obstacle circuits
FRIDAY AUGUST 30	Trial 4 — Cross-country speed test circuit Trial 5 — Point-to-point courses

TERRAIN DESCRIPTION AND SIGNIFICANCE

TEST SITE A — ORGANIC TERRAIN COVER, G CLASS

Fig. 5 typifies G cover in a high-water regime. Directly beneath the surface of the water, peat of an amorphous granular type predominates in depth. The peat is commonly 4 to 15 ft. deep, and at all depths lacks cohesiveness. Bearing capacity is at its lowest in such terrain.

It frequently recurs in confined muskeg and is found on, or close to, the edge of the so-called floating mat.

Where a change in cover type is experienced, the amorphous granular peat is overridden by a coarser type containing more fiber, sometimes woody, sometimes not. The transition is abrupt.

Prior to these tests, no vehicles were known that could traverse this terrain. When the water content in a dry season changes from high to medium, the RAT (Appendix 1) may with occasional success traverse it, but difficulty is experienced when the vehicle reaches a different cover class at the peat interface (Fig. 6), and frequently finds it impossible to mount the mat.

Thus, experience has shown that immobilization can be expected until a device is available to effect recovery. One vehicle that has such a device is the Water Buffalo (Appendix 1) but in traversing this terrain it depends fully on buoyancy and has no traction, its power being applied to an anchored cable (Fig. 7). When the Water Buffalo in such circumstances attempts to traverse the mat at the interface, the tension on a 3/4-in. cable is sufficient to snap it at the lower pulley close to the bow of the vehicle. The chances of this occurring are about 8 in 10 when the cover change is from G to EI, but are appreciably lower when the cover change is from G to FI and FEI.

TEST SITE B — ORGANIC TERRAIN COVER, FORMULA FEI

Fig. 8 is representative of this type of organic terrain in a high-water regime. A comparison of the photograph with that for class G (Fig. 5) shows marked differences. The areas of FEI are not completely homogeneous except in a superficial sense. Occasionally, islands of EFI interrupt the FEI and, where this occurs, the intrusion causes a rise in surface contour constituting a microtopographic element. Another typical interruption is the occurrence, in patches, of FI.

Prior to these tests, all vehicles with the exception of the Water Buffalo could be immobilized eventually, and most were immobilized in the first few passes. The Water Buffalo is dependent on use of the cable.

The peat categories below this cover are amorphous granular, fine fibrous with the fiber only occasionally woody, except for the localized EFI, in which the fibrous constituent becomes so plentiful as to be significant in its contribution to increased bearing capacity.

FEI and the peats with which it is associated are common constituents in confined muskeg. In unconfined muskeg, FEI usually gives way to either homogeneous FI, EI, EH and HE, the latter two types being frequent when water regime is medium to low.

TEST SITE C — ORGANIC TERRAIN COVER, FORMULA DI

This cover formula is typified in Fig. 9. Here, surface obstruction is important, especially in relation to movement of light vehicles.

The feature of greatest significance in this kind of organic terrain is microtopographic. So-called "traps" occur frequently (every 3 or 4 feet), as holes with abrupt margins. Unless a vehicle can crush the cover to form a mat over the traps, one track or part of a track will become submerged and, if the approach angle is inappropriate, the vehicle will not rise and will become immobilized.

Immobilization is partly due to the peat in the traps being amorphous granular and having negligible bearing capacity.

Maneuverability on this kind of organic terrain is poor. Normally, if a vehicle is able to enter the cover, tracks may be thrown, steering cables broken, deviation from access route be excessive, and mechanical breakdown usually can be expected on even a short traverse of 100 ft. Because of its weight, wide rugged tracks, and its approach angle, the Water Buffalo makes ideal progress on this terrain, and travels in a straight line at optimum speed.

The peat type is amorphous granular, coarse woody fibrous with fine fibrous intermixed. It is frequently associated with DEI and DFI cover. The former has smaller traps and the peat constituent is more homogeneous; while the latter has larger traps, bigger areas of amorphous granular fine fibrous non-woody peat, and D class cover in clumps 8 to 12 ft. apart.

This type of organic terrain occurs in both confined and unconfined conditions, is often only 2 ft. deep and seldom exceeds 3 or 4 ft. in depth. Where a high-water regime occurs, the water is obviously flowing. It occurs in laggs, and forms channel-like vistas at the head of, and throughout, shallow drainage gradients.

TEST SITE D — ORGANIC TERRAIN COVER, FORMULA BFI

Fig. 10 shows this category in a medium-water regime. The importance of surface obstruction is marked. The trees constitute dominant cover and the formula as a whole

designates the presence in 8 to 10 ft. depths (commonly) of coarse fibrous in non-woody fine fibrous peat, in which woody elements occasionally occur.

Most muskeg vehicles can traverse this terrain, but often after two or three passes they are immobilized in localized FI conditions.

The FI formula is common and occurs in unconfined as well as confined muskeg. It marks the position of local reservoirs of hidden ground-water, often on a generalized, shallow drainage gradient.

TEST SITE E — ORGANIC TERRAIN COVER, FORMULA EI

Fig. 11 demonstrates a typical EI cover in a high-water regime. It occurs sporadically to form microtopographic features designated as mounds, and shown in Fig. 12.

In either case, the common depth is from 8 to 20 ft. in confined terrain, and from 4 to 10 ft. in unconfined terrain.

All muskeg vehicles can complete the greatest number of passes in this terrain, provided the water regime is from medium to low, but when subsidence occurs between the mounds, immobilization results. Often immobilization is brought about by pitching, induced by the effect of the mounds on the vehicle which produces ground pressure concentrations at weak places in the terrain.

Woody fine fibrous peat occurs where the terrain is homogeneous and not interrupted by a background of FI, as shown in Fig. 12. Here, at intervals of 10 to 15 ft., non-woody fibrous peat occurs, and this in turn is sometimes interrupted by amorphous granular, fine fibrous peat.

Mixed Vegetal Cover

In addition to the common organic terrain cover types, there is a heterogeneous cover typifying the pre-Cambrian terrain. This and the mineral layer beneath it can be visualized by an examination of Fig. 13.

Mixed muskeg and mineral terrain has variable cover, as shown in Fig. 14.

An appreciation of the terrain as described above may be gained from the aerial photograph of the Dinner Lake Trials area (Appendix 2).

RESULTS OF THE TRIALS PROGRAM

TESTS (A AND B) — TEST SITE A

The tests in Area A were not continued beyond four passes, as it was obvious that neither vehicle would become immobilized, but would find "easier going" as it created a canal.

Vehicle A (payload of 128 lb. plus driver)

Vehicle A experienced some difficulty mounting detached or lightly anchored masses of floating vegetation, and was thrown off course or swung around until it was perpendicular to the edge of the mass.

The right-hand engine stalled during the 1st, 2nd and 3rd runs, but was not detected by the driver until it was made obvious by inability to correct the resulting turn by throttle manipulation. The idling speed was advanced to correct the engine failure, but on later occurrences of one engine stalling, the driver did not always immediately detect the difference by noise level.

Vehicle A has jet impellers in the lower rear end of the hull for water propulsion and these were in operation during the first two runs. The drivers were instructed by the owner to sit towards the rear (on the seat-back), so that the jet outlets would operate at an optimum level. When the belt drives to the jet impellers were disconnected it seemed that the wheels gained power, and the vehicle proceeded with much splashing.

Times varied between 50 sec. (no jets, high gear) and 70 sec. (jets, low gear) for 100 ft. (1.36 to 0.97 m.p.h.). This was contrary to the expectation of the owner.

Vehicle B (payload of 348 lb. plus driver)

There was some steering difficulty mainly due to a lag in response and consequent oversteering by the inexperienced drivers. The four 100-ft. runs were completed in 38 to 51 sec. (1.79 to 1.34 m.p.h.).

There was some splashing and, because no splash guards were fitted, 1 1/2 in. of water collected in the bottom of the hull.

As indicated previously, the RAT has had some success in this area, but its inability to mount the mat edge and the relative ineffectiveness of its steering under these circumstances make its performance inferior to that of either Vehicle A or B.

TESTS (A AND B) — TEST SITE B

On the areas used for the tests,the cover occasionally changed from FEI to FIE. Bearing capacity for this terrain (FIE) is slightly less than that for FEI, but for both vehicles tested this condition had no effect.

Minimum speed was not measurable, as throttle control was not fine enough to avoid involuntary stops. However, it was possible to control either vehicle from outside and to walk beside it under most circumstances, although a foot throttle was substituted for the hand control of Vehicle B when it was returned for testing in October.

Vehicle A: The owner requested a test with sectional aluminum tracks fitted (Figs. 1 and 2).

Time for a run of 100 ft. averaged 15 sec. (4.55 m.p.h.); time for a turn 12 to 20 sec. When the turn at the lake end of the lane involved maneuvering in open water and mounting the mat edge, it was found that it was best to bump the vehicle into the edge of the mat (if it had been approached at an angle) until it swung around perpendicular to the edge, when both tracks would gain purchase. If the mat edge was approached slowly (at an angle), the one track that made contact would often turn the vehicle away.

After 38 passes, while turning on the firm mat, the right rear half-shaft sheared (chain came off sprocket). This took 2 hours to repair.

Vehicle A later completed 50 passes without tracks, and acceleration tests were completed in the same general area.

FEI-FIE cover and associated conditions provided no difficulties for this vehicle. The tracks tore the surface vegetation more than the wheels, but there was no tendency for material to collect around axles, as is the case with the RAT (Fig. 15).

Vehicle B: The vehicle was plagued by flat tires throughout the test. The owner had not received new tires and was using those from his prototype machine.

Only 16 runs were completed because of the frequency of tire failure. It took 50 sec. to change a tire but longer to prepare spares.

Average time for a run was 25 sec. (2.73 m.p.h.).

Time for a turn on FIE, 35 sec. and on water 60 sec. This longer time was largely because the steering cable system was slack and turning could not be done in a short radius. The vehicle could not be held in a turn and there was much backing and maneuvering.

There was also some slippage of the track belt on the drive as the belt became wet, and vegetation was carried around the wheel. When the vehicle was being driven back to the highway for maintenance, an attempted sharp turn on a bank of firm peat at the berm caused the belt on one side to slip from the rear drive wheel. The wheel has to be deflated in order to replace the belt. The machine must then be moved forward while the belt is fed onto the drive wheel. This would be difficult, if not impossible, for one man to do. The track belts were later shortened by 1 1/2 in.

Comments: As the water regime in this area was quite high, subsidence was not measurable; the slight impression made by the vehicles was eradicated by rebound of the mat after they had passed.

Figs. 16 and 17 are photographs of these tests. Fig. 18 shows the RAT in similar terrain, and it is seen that surface deterioration is greater than that produced by either Vehicle A or B. The RAT was tested previously in 6 FEI sites and was immobilized in 3 sites, on the 1st, 9th, and 25th passes.

TEST (A) — TEST SITE C — DI

It was considered impractical, owing to the size and weight limitations of the vehicles, to set up a fully instrumented course. Cone penetrometer data would have meant little when the main hindrance to progress was surface obstruction. Consequently, an area of DI was chosen, and the owners were asked to take the vehicles across in a manner that they would recommend for normal operation. It was considered that the hazards were sufficiently unusual to require owner decisions, rather than entrust the test to relatively inexperienced drivers.

Vehicle A: The vehicle was controlled from outside and driven with force into an area where elements of D were scattered on 6 to 8 ft. centers and with branches between 1 and 2 in. in diameter. The vehicle mounted bushes, almost overturned, was jumped on by the driver in order to break down vegetation, and was generally thrust and man-handled through a 100-ft. (approx.) semi-circular course.

The attack was furious, but not always fast. The vehicle was light enough to be man-handled into advantageous positions, and judicious use of engine controls could assist, but the process appeared very fatiguing. The lightness detracts from the vehicle's ability to crush the heavier members of D.

The traps in D are not significant, as the coarse cover wards off the vehicle from the basal trap area.

The vehicle can be man-handled through D, but the operation is strenuous and should be limited to traverses of lagg areas or stream boundaries; extensive areas should be avoided.

Vehicle B: This vehicle was tested in October.

Its performance was similar in some respects to that of Vehicle A, but it was not as maneuverable and therefore had to attempt obstacles directly in its line of travel. Its greater weight, however, gave it superior obstacle climbing and crushing ability.

The owner was more concerned with vehicle damage than the Vehicle A owner, and consequently he stopped more often to consider each situation and sometimes to attempt to clear obstacles or improve conditions.

Because of the greater weight, this vehicle might possibly travel more easily, with less strain on the driver, than Vehicle A in D country; however, it would be best to avoid this cover class as much as possible.

Neither vehicle suffered tire damage.

No performance data are available for the RAT in these circumstances, but it would no doubt have difficulty in negotiating the coarse cover and basal traps.

TEST (A) — TEST SITE D — BFI

On this site, the cover occasionally changed from BFI to BEI, and the strength of the mat then became appreciably greater because of a woody fine fibrous texture as a main constituent of the peat. The influence of the change in cover sometimes induced pitching, because E cover is accompanied by local mounding, but appeared to have no effect on performance.

Again, because surface obstacles seemed to be the limiting factor and it was evident that either vehicle could accomplish 50 or an indefinite number of passes on the firm surface, no multiple pass tests were made.

Speed tests were carried out and observations were made. Figs. 19 and 20 are photographs of these tests.

Vehicle A: A 100-ft. course that included approximately 15 trees at 6 to 8 ft. centers and of 1 to 3 in. in diameter was selected, and the drivers were instructed to hold as straight a course as possible.

The vehicle was thrown off course by encountering slight mounds and so avoided some of the larger diameter trees, but it did knock down and travel over 1- and 2-in. trees of about 12 ft. height.

On two runs (in 12.4 and 12.8 sec.) it averaged 5.41 m.p.h.

Vehicle B: Vehicle B was tested in October.

It encountered slightly larger trees than Vehicle A, and in running up the rather rigid trunks of a small group of about 1- to 2 1/2-in. trees, it came close to overturning. Again the weight factor helped, as on the 3rd run the vehicle was able to ride over a 2 1/2-in. tree.

On two runs (12.0 and 12.7 sec.) it averaged 5.5 m.p.h.

No performance data are available for the RAT in these circumstances.

TEST (A) — TEST SITE E — EI

As the cross-country course had large areas of EI terrain on which performance could be judged, normal tests were not carried out on this site. However, it was thought that EI

mounding (which was not well marked on the cross-country course) might affect performance, and testing was done in Area 1, an area previously documented as to cone penetrometer values, etc. EI mounding occurred in FI background.

Figs. 21 and 22 show these tests.

Vehicle A: The mounds were firm because of the presence of Polytrichum as the moss component. The vehicle pitched violently and, at speed, actually left the surface and appeared to leap from the tops of mounds.

On two runs (8.3 and 7.9 sec.) it averaged 8.42 m.p.h.

At the owner's request the vehicle carried two and then three passengers in unofficial tests, and pitching was less violent because the mounds were squashed down.

Vehicle B: The vehicle was tested in October.

It made two runs (14.8 and 12.4 sec.) and averaged 5.05 m.p.h.

Pitching was not as violent as with Vehicle A, but there was some steering difficulty — a lack of responsiveness.

The vehicle sustained a flat tire in unofficial runs in this area.

The RAT was tested in three EI sites and completed 40 passes successfully in each. However, it has a tendency to collect plant material in its track supports.

TEST (B) — MINIMUM TURNING RADIUS AT HIGH SPEED

This was difficult to determine.

In Vehicle A it was found possible, as drivers became experienced, to make tight turns (in situ), but there was always the danger of overturning if the terrain were not level. (Two estimates were 10 ft. and 12 ft. radius).

If Vehicle B were turned too quickly, the belt, if wet, would slip and chatter, but in a properly executed turn, the turning radius was about 4 to 5 ft. However, Vehicle B had the advantage of a reverse gear, so that its maneuverability approached that of Vehicle A without the necessity of dismounting and man-handling.

TEST (C) — ACCELERATION

No acceleration tests were conducted in Site A because of the difficulty of placing observers.

In Sites C, D, and E, it was felt that differences in the number, spacing, or size of obstacles in the lanes would make comparison of results meaningless.

Tests were conducted in Site B, where lanes were judged to be almost identical.

Vehicle A: Vehicle A reached a 25-ft. mark from a standing start after 3 sec. (5.6 m.p.h. av.), 50 ft. in 6.1 sec. (5.6 m.p.h. av.), and 100 ft. in 9.2 sec. (7.4 m.p.h. av.).

Vehicle B: In August, this vehicle was operating with a transmission with the wrong gear ratios — its highest gear was available only in reverse. Attempted tests in reverse were not successful.

In forward gear the vehicle reached 25 ft. from a standing start in 6.8 sec. (2.5 m.p.h. av.), 50 ft. in 11.6 sec. (2.9 m.p.h. av.), and 100 ft. in 21 sec. (3.25 m.p.h. av.).

Water Trials

Test (a) — Both vehicles were buoyant and controllable, and this was demonstrated by the owners within the first 30 min. of the test period.

Test (b) — A test lane was marked by buoys and sighting stakes on land.

Each vehicle reached maximum speed prior to crossing the starting line and then maintained speed until the course was completed. The course was then run in the opposite direction.

A light breeze from the NW held for all tests.

Figs. 23 and 24 show these tests.

Vehicle A:

		SW to NE	NE to SW		
Driver A	With jets	40.5 sec.	39.0 sec.	Av. 40 sec.	(1.70 m.p.h.)
	Without jets	39.3 sec.	39.0 sec.	Av. 39 sec.	(1.75 m.p.h.)
Driver B	With jets	35.0 sec.	38.6 sec.	Av. 37 sec.	(1.84 m.p.h.)
	Without jets	37.6 sec.	39.0 sec.	Av. 38 sec.	(1.79 m.p.h.)
		With jets	Av. speed	1.77 m.p.h.	
		Without jets	Av. speed	1.77 m.p.h.	

Both drivers commented on poor steering control without jets. The driver sat to the rear of the vehicle (on top of the seat-back) to depress the jets to the proper depth. When the jets were not operating the wheels were able to turn faster, but this did not improve the speed; it merely increased the splashing and amount of water shipped.

NOTE: If a fixed load has to be carried, the largest available space is under the bow deck just aft of the fuel tank (a shelf was provided at this location), but a load placed here would require even more gymnastics by the driver, to achieve balance when buoyant.

Vehicle B: The high reverse gear in the transmission led to an owner request that the water speed trial of his vehicle be run in reverse.

Three runs were made in each direction.

		SW to NE	NE to SW		
Driver A	Forward	48.4 sec.	49.8 sec.	Av. 49 sec.	(1.39 m.p.h.)
	Reverse	34.0 sec.	37.2 sec.	Av. 36 sec.	(1.89 m.p.h.)
Driver B	Forward	40.2 sec.	42.4 sec.	Av. 41 sec.	(1.66 m.p.h.)

The vehicle did obtain better speed in reverse, but there was a great deal of splashing, and water was thrown into the hull and over the driver's legs. The better speed obtained by driver B seemed to result from his following the advice of the owner to lean forward and so level the vehicle in a fore and aft direction.

It was decided to run the water speed test again in October when the vehicle had its correct transmission installed. Two runs were made.

		SW to NE	NE to SW		
Driver A	Forward	30.2 sec.	34.2 sec.	Av. 32 sec.	(2.14 m.p.h.)

Splash guards had been fitted and these, while flimsy (and later damaged beyond repair), did prevent the excessive splashing from entering the hull.

In Fig. 24, Vehicle B has the new transmission installed.

TEST (D) — MANEUVERABILITY

Vehicle A: The use of jets improved steerability remarkably. However, if a high-speed turn was attempted (one engine slowed, the other speeded up), the 25° lugs on the tires induced a crab-like movement of the vehicle towards the slowed side.

The tightness of the turn could be improved by leaning in, the driver even hanging over the edge of the vehicle on the inner side. This seemed to produce the desired effect by submerging the inside wheels and thus producing drag, and by exposing only the lower halves of the outside wheels and improving the paddle action. Turning radius with jets — 5 ft. without jets — 3 ft.

Vehicle B: This vehicle has the advantage of a reverse gear and a positive paddle action. It is therefore quite maneuverable, with a turning radius of 5 to 10 ft. However, at speed, the paddle action in a turn seems to become less positive, and driver A reported that the controls actually reverse, i.e. when the right track is accelerated to achieve a left turn, the vehicle turns to the right.

It is not known why this occurs, but a partial explanation may be that, as the outside track is accelerated, the drag increases at a greater rate than the propulsive effect and that the inside track, which does not stop completely, has a net propulsive effect greater than the outside. In addition, it was noted that as the speed of the tracks increased, the vehicle's rear was depressed; in a turn it is thus the faster, outside track that rides lower and so incurs greater drag.

The RAT has not been tested in similar circumstances but, from observation of its progress across Dinner Lake in a stiff breeze, it is not as steerable as either Vehicle A or B, and is slower.

SHORT TRAILS ON MINERAL TERRAIN

Test (a) The 200-yard course was reasonably rugged with rock ledges, boulders, a small copse, and a slight incline rising in a northerly direction.

Vehicle A: The vehicle negotiated all obstacles with comparative ease. The drivers, now experienced, had learned how to handle sensitive engine controls and to ride the vehicle by shifting their weight to aid in balance and steering.

The mode of travel recommended by the owner for rough going is to drive with one leg over the side of the vehicle. This would be uncomfortable over long periods, but with a vehicle of this size and weight the driver must be ready to jump quickly in the event of a spill. When a small rock ledge is encountered at speed, the vehicle will actually leave the ground for 3 to 4 ft.

	S to N	N to S		
Driver A	52.4 sec.	51.6 sec.	Av. 52 sec.	(7.87 m.p.h.)
Driver B	46.2 sec.	41.6 sec.	Av. 44 sec.	(9.30 m.p.h.)

Vehicle B: The steering was lagging or unresponsive, and on the first pass the driver hit a 4-in. tree. The test fuel tank was jarred loose, and the vehicle returned to the starting line.

The test was re-run, and at the end the vehicle had 3 flat tires, a broken cast-iron hub, and a broken aluminum wheel. This damage caused its withdrawal from the tests, as no spares were available. Time, S to N – 56 sec. (7.3 m.p.h.)

The test was performed again in October. On the second run, the vehicle had two flat tires (not punctures but deflated due to twisting-off of hub beading that was not always securely held by the large hose-clips). It also proved slightly unresponsive to steering control and again ran into a tree. The two measured runs were obviously much more comfortable for the drivers than in the Vehicle A tests. The driver in the seat was not thrown about, and did not find it necessary to shift about to preserve vehicle balance.

Times	S to N	N to S		
Driver A	63.2 sec.	60.4 sec.	Av. 62 sec.	(6.6 m.p.h.)
Driver B	59.4 sec.	53.4 sec.	Av. 56 sec.	(7.3 m.p.h.)

The steering problems disappeared later, when adjustments were made.

No performance data are available for the RAT in these circumstances, but from experience in the same general area its performance is estimated to be on a par with Vehicles A and B.

Test (b) The obstacle course was run over the course much as marked on the large map (Appendix 2), but included a loop that took the vehicles through a small copse of 6- to 10-in. trees at about 8-ft. spacing. The ground cover consisted of tall (3 ft.) ferns that hid possible deadfalls or stumps from the driver's view, and so encouraged a cautious approach coupled with a need to exploit to the full the maneuverability of the vehicle in unexpected situations.

Vehicle A: The vehicle easily negotiated all obstacles (indicated on maps and photographs).

It may be driven over the edge of ledges as much as 15 to 18 in. high with safety, if the line of travel is perpendicular to the edge; otherwise there is likelihood of tipping; but the driver should be ready to jump clear at any time.

When obstacles larger than this are met, it is best to dismount and walk the vehicle over, down, or around by controlling the hand throttles from outside.

The copse proved difficult to negotiate, largely because of the closeness of the trees and the need to man-handle the vehicle into more advantageous positions. This occurred despite the fact that the vehicle can be controlled from outside, because without reversing capability it cannot be backed out of an impasse.

Vehicle B: The vehicle can be driven with the driver in normal position over most obstacles, such as ledges and boulders less than 18 in. high. It is best to tackle these squarely to avoid tipping, and for larger obstacles to dismount and control the vehicle from outside; although outside control has been made difficult by the substitution of a foot control for the original hand throttle.

It cannot turn as short as can Vehicle A, but it has a reversing advantage.

While the driver was dodging branches in the copse he inadvertently applied full throttle and crashed into a tree. One aluminum wheel axle snapped and left only 7 wheels on the right side. In subsequent maneuvering, the vehicle easily rode over 2-in. brush, but as the driver could not man-handle the vehicle and had to rely on repeated forward and backward runs in order to gain a new direction within the confined turning area, progress through the copse was slower than that of Vehicle A.

Difficulty was also experienced in climbing the 30-in. "bullnosed" rock ledge at the edge of the copse.

No performance data are available for the RAT in these circumstances, but from experience with it in attempting to surmount small ledges, ridges, and boulders, its obstacle-climbing ability is known to be inferior to that of either Vehicle A or B.

CROSS-COUNTRY COURSE

TEST (a) – (SEE FAMILIARIZATION AND OBSTACLE TEST CIRCUIT)

One driver drove Vehicle A while the other followed on foot so that both became familiar with the course boundaries and the obstacles to be attempted.

Vehicle B was out of commission at this time. When it was returned to the area in October to complete tests, it was not subjected to this portion of the program, as its general capabilities were known.

Vehicle A: It was apparent that the course was initially more a test of driver skill and experience than of vehicle performance.

The vehicle failed to negotiate several obstacles at the first attempt mainly because the driver was uncertain in his use of technique.

It had been learned from the owners that normal practice would be for the driver to dismount before apparently difficult obstacles and "walk" the vehicle over with outside control. During the first circuit, this method was resorted to more frequently than the owner of Vehicle A considered necessary. He demonstrated the approach to certain obstacles and aided in the familiarization process.

Rock ledges, a beaver channel (Fig. 25), shore margins, and other significant obstacles were overcome by this vehicle (with the driver aboard), if tackled vigorously and with what might appear to be excessive speed. The large soft tires cushioned the shock of sudden contact, and the resulting strong rebound often seemed forcibly to recover the vehicle from an incipient spill, whereas a slower encounter might force the driver to leave the vehicle quickly in order to preserve balance.

Because of frequent halts for discussion or photographic purposes, the first circuit took approximately three hours to complete.

TEST (b) – (SEE SPEED TEST CIRCUIT)

Vehicle A carried a payload of 100 lb. in addition to the driver.

First Circuit, Driver A

No difficulties were encountered over Sections 1 and 2. Obstructions up to the edge of the bog shown in Section 3 were easily negotiated, as were the open water and edge of mat in Sections 4 and 5.

The steep rise (Section 6) and fall (Section 7) were negotiated with the driver alongside. He had to dismount again at the beaver channel, which had been a difficult obstacle during the familiarization circuit, but he had no great difficulties until thrown from the vehicle when

attempting to negotiate the cleft shown in Section 11. This mishap resulted from his failure to make proper adjustments in speed, angle of approach, and perhaps body movements to maintain balance. Body movements seemed necessary whenever the vehicle assumed a greater angle of lean than about 20°, or angles of pitch greater than 30°.

The vehicle made good time through all sections, with only occasional halts to assess the difficulty of an obstacle, until it was required to climb the rock face shown in Section 18. The driver chose to take the vehicle up a less steep slope outside the boundary of the course, after his first attempt almost resulted in an upset.

The course then (Section 21) became less rugged, and no problems arose. The vehicle was driven at speed over the rock step into open water, and made a level "six-point" landing without shipping water.

The remainder of the course to the duck-blind was uneventful, and the running time was 34 min., 59 sec. Fuel consumption was 2,720 c.c. or 0.598 Imp. gal.

2nd Circuit, Driver B

Progress through Sections 1 and 5 was uneventful, except that three attempts were required to mount the edge of the EI mat from open water (Section 5), as it was approached at an incorrect angle and the vehicle turned away.

The steep rise (Section 6) and fall (Section 7) were attempted with the driver aboard, and Fig. 26 provides good evidence of the difficulty of these obstacles, and of the effort required of the driver in order to stay in the vehicle. When the beaver channel was reached, the vehicle stopped in a nose-down position in the channel and the engine stalled. This was caused by dislodgement of the loosely fitted fiberglass fuel tank, which disconnected the plastic fuel line.

The connection was restored and the vehicle proceeded with good speed to Section 10. Here it was delayed in open water near the beaver lodge, while the driver attempted to steer the vehicle over an accumulation of sticks and trash without success. He did not detect the failure of one engine and could not steer in the desired direction. Three minutes were lost before the cause was corrected.

In an effort to make up lost time, the driver attempted several obstacles in Section 11 at high speed, and was forced to abandon the machine several times because of incipient upsets.

The exit from the water and up the rock face in Section 18 was accomplished in impressive manner, though requiring agility of the driver.

The course was completed with ease, and the running time was 41 min., 40 sec. No fuel consumption value was recorded because of spillage. The total elapsed time was approximately 1 1/2 hr., because of time to repair the fuel system, to redistribute and fasten the payload, and to repair a broken jet-impeller drive belt.

Vehicle B: This vehicle was tested in October.

It carried 18.6 gal. of water in its sponsons as a simulated auxiliary fuel supply and as part of its payload for test purposes. The water was retained throughout both test circuits. In addition to this 186 lb. load, it carried a 40-lb. toolbox and two 10-lb. spare wheels, a total of 246 lb. without driver.

First Circuit, Driver B

The vehicle had no difficulty until it reached the sharp rise (Section 6), where it turned over after being driven at the obstacle at high speed. The driver had jumped out a moment

before. The engine stalled, and the vehicle was righted with no difficulty. One fiberglass splash guard had been damaged and there was an impact scar on the front deck.

Time was lost at the beaver channel, where the vehicle had to be maneuvered backwards and forwards in order to lift the left track out of the channel and, when this was done, to avoid stumps. Part of the track guide broke off on a stump, and the vehicle was unable to proceed until two men helped the driver to extricate it.

A stump, near the beaver lodge, Section 10, provided difficulties and caused delay, but by use of the reverse gear the driver was able to maneuver without leaving his seat.

The exit from the bog shown in Section 17 required two attempts before it was surmounted, and the steep exit from open water in Section 18 could not be negotiated (Fig. 27) and had to be by-passed.

No further difficulties arose, and the vehicle's performance at the two remaining obstacles of any significance, the rock ledge in Section 21 and the slope in Section 24, was faultless.

Running time was 37 min., 20 sec. Fuel consumption was 2,110 c.c. or 0.464 Imp. gal.

<u>Second Circuit, Driver A</u>

The driver "walked" the vehicle over the Section 6 and 7 obstacles without difficulties, and made good time to the beaver channel (Section 8).

The vehicle negotiated the channel with little difficulty, but in maneuvering to avoid stumps and to make the necessary 90° turn, three tires were deflated. The probable cause was poor steering response that imposed severe side loads on the tires and induced leakage from the hose clips at the wheel hubs.

The remainder of the circuit was made difficult by poor steering response and another tire deflated at the rock face, Section 18.

Running time was 41 min., 22 sec. No fuel consumption data were obtained, as the gauge-glass on the test fuel tank broke when the tank became dislodged.

<u>Third Circuit, Driver B</u>

A further test was made after the steering mechanism had been adjusted and the tires inflated to a higher pressure.

An alternative route was taken around the obstacle in Section 6, but the driver drove the vehicle down the obstacle in Section 7 without difficulty.

The beaver channel was crossed with ease at the first attempt and without need for the driver to dismount. The rock face in Section 18 was by-passed.

No problems arose until the open water in Sections 22 and 23 was reached, when the engine failed due to fuel starvation. The temporary position of the fuel tank would not allow gravity feed when the fuel supply was low. This was corrected, and the vehicle completed the course in a running time of 27 min., 12 sec. No fuel consumption data were obtained.

No performance data are available for the RAT in these circumstances, but the ability of this vehicle to complete more than 50 per cent of the course is seriously doubted.

Selected pictures of the cross-country course are shown in Figs. 28 to 37, the numbers indicating the locations marked on the sectional maps where the photographs were taken.

Point-to-Point Courses

None was attempted, for lack of time.

RECORDS

Cone penetrometer values are given in Appendix 3.

Measurements of performance are given in the text under the various test headings and also collated in Table 1. No similar measurements are available for the RAT.

Figure of Merit

It was not possible to make more than two circuits of the cross-country course with Vehicle A or three with Vehicle B. Fuel consumption was obtained for one circuit only by each vehicle. Neither vehicle carried its full specified payload.

Because of this lack of data, little confidence is placed in the following computations as true "figures of merit", calculated as: $FM = \dfrac{\text{payload (lb.)}}{\text{fuel (gal.)} \times \text{time (min.)}}$

$$\text{Vehicle A} - FM = \frac{100}{0.598 \times 35} = 4.77$$

$$\text{Vehicle B} - FM = \frac{246}{0.464 \times 37\ 1/3} = 14.2$$

DISCUSSION AND CONCLUSION

Metal flanges and hubs were used to provide high-density payloads, but neither vehicle could accommodate its specified full load. Neither had adequate provision for stowing or securing loads and, because of the need in each to distribute the load to maintain stability, the drivers' foot-space was cut down. Concern with shifting loads and possible injury may therefore have militated against full exploitation of the vehicles' capabilities.

While both owners were helpful in indicating handling methods, it was apparent that they had not previously exposed their vehicles to some of the difficulties presented by organic and associated terrain, and driving techniques had to be developed as the tests proceeded. This need, and control problems such as the sensitive throttle of Vehicle A or the occasionally maladjusted steering system of Vehicle B, also may have limited performance.

To surmount an obstacle such as a moderately steep rock ledge, the operator of Vehicle A would bring it to the foot of the ledge, turn the throttle twist-grip fully forward, and allow the vehicle to surge forward unaccompanied. The spring-loaded throttle would then cut the engine back to idling, bringing the vehicle to a halt a short way beyond the obstacle, and so allow the driver to negotiate the obstacle alone and resume control.

Vehicle B, on the other hand, would be accompanied over the obstacle by the driver, who was required to reach over the moving upper wheels to retain throttle control and be prepared to leap clear should the machine topple or should he not be able to keep pace with it.

TABLE 1

Test Site	Cover	VEHICLE A Payload	VEHICLE A Times and Speeds	VEHICLE B Payload	VEHICLE B Times and Speeds
			100-ft. course		100-ft. course
A	G	128 lb. + driver	50 sec. (no jets, high gear) = 1.36 m.p.h. 70 sec. (jets, low gear) = 0.97 m.p.h.	348 lb. + driver	38 to 51 sec. = = 1.79 to 1.34 m.p.h.
B	FEI	128 lb. + driver	15 sec. (with tracks) = 4.55 m.p.h.	348 lb. + driver	25 sec. = 2.73 m.p.h.
			Acceleration tests		Acceleration tests
		25 ft.	3 sec. = 5.6 m.p.h.	25 ft.	6.8 sec. = 2.5 m.p.h.
		50 ft.	6.1 sec. = 5.6 m.p.h.	50 ft.	11.6 sec. = 2.9 m.p.h.
		100 ft.	9.2 sec. = 7.4 m.p.h.	100 ft.	21.0 sec. = 3.25 m.p.h.
C	DI		NOT TIMED		NOT TIMED
D	BFI	170 lb. + driver	12.4 and 12.8 sec. = 5.41 m.p.h. av.	246 lb. + driver	12.0 and 12.7 sec. = 5.5 m.p.h. av.
E	EI	170 lb. + driver	8.3 and 7.9 sec. = 8.42 m.p.h. av.	246 lb. + driver	14.8 and 12.4 sec. = 5.05 m.p.h. av.
Water		128 lb. + driver	with jets 1.77 m.p.h. av. without jets 1.77 m.p.h. av.		2.14 m.p.h.
			600-ft. course		600-ft. course
Short Inorganic Trail Speed Test		100 lb. + driver	A. 7.87 m.p.h. B. 9.30 m.p.h.	246 lb. + driver	A. 6.6 m.p.h. B. 7.3 m.p.h.
Cross-country		100 lb. + driver	A. 34 min. 59 sec. B. 41 min. 40 sec. 2.1 to 2.6 m.p.h. approx.	246 lb. + driver	A. 41 min. 22 sec. B. 37 min. 20 sec. 27 min. 12 sec. 2.2 to 3.3 m.p.h. approx.

The difference in success in obstacle climbing would seem to lie not in ultimate capability, but in methods of control. If both vehicles were equipped with a 10-ft. cable control to the throttle, their ability to surmount obstacles would probably be about equal.

The observations of the relative climbing ability of the two vehicles, with driver aboard, are shown here graphically. No tests were designed to arrive at a more accurate assessment. We question the "Tipping Angle — side slope with full load" value of 62°, given in the specifications of Vehicle A; this is obviously not attainable with the driver aboard, and improbable with the payload placed anywhere but on the floor of the vehicle.

One important conclusion from these tests is that both vehicles are able to remain mobile and move effectively in any kind of muskeg, insofar as bearing capacity of the terrain is concerned. In this respect these vehicles are unique. For instance, both vehicles can maintain mobility on terrain in which the M29C tracked vehicle bogged down (Fig. 38). The Water Buffalo, the only other vehicle that can negotiate all categories of muskeg, can do so only with the aid of power applied to an anchored cable. Vehicles designed along the lines of those tested will therefore be useful anywhere in Canada where muskeg occurs, provided other aspects of organic terrain such as surface obstruction, or inherent mechanical design characteristics of the vehicles, do not limit the operation. It is emphasized that these two vehicles are the first to give this indication, and show great promise with respect to off-road activities with a light payload.

Their performance on mineral terrain is equally successful, there being virtually no trafficability problems insofar as practical mobility is concerned. Limitations to forward travel are similar to those applying for organic terrain.

Performance on still water, including the activity of entering and leaving water, is satisfactory, but the low maximum speeds attainable may limit the usefulness of these vehicles in even moderate currents.

The cone penetrometer values are useful for identifying the strength of the terrain in depth. They are given in Appendix 3 for those types of terrain normally regarded as critical for supporting traffic. Since immobilization as a function of subsidence and remolding was not experienced, cone index ratings cannot be ascribed to either of the vehicles.

OATRU is somewhat hesitant to draw any conclusion as to which is the better vehicle. The main reason for this attitude is that neither vehicle has been fully developed. Alterations were made even as the tests were in progress. Also, measurement devices to assess performance were not available, because they could not be designed and developed in time. However, if the reader refers to the Summary of Performance Appraisal, which follows, he will probably conclude, as did OATRU, that Vehicle B at the present stage is slightly more successful than Vehicle A.

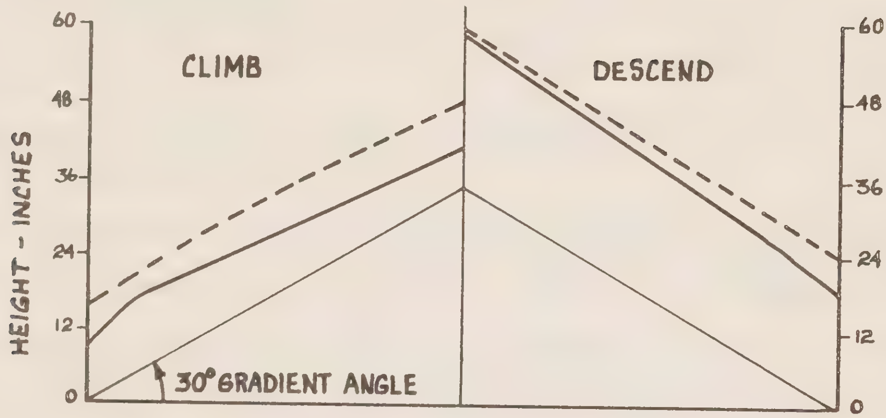
For the purposes of this Summary, the maximum appraisal of each characteristic or performance of an activity was set at 100 per cent. The comparative success of each vehicle in approaching the maximum was then estimated as a percentage, and taken as an index of relative performance. A higher figure in each pair therefore indicates the vehicle with the better characteristic or performance; in a few, they were regarded as equal.

The average of all evaluations for each vehicle (given at the foot of the table) provides a relative performance index, but this is pertinent only when performance features are weighted equally. It is about 10 per cent in favor of Vehicle B.

SUMMARY OF PERFORMANCE APPRAISAL

Activity or Characteristic	Vehicle A	Vehicle B	Remarks
General design	60	80	to cope with approach, etc.
Length of vehicle (longitudinal stability)	50	100	see photos of Vehicle A standing on end inappropriate to microtopography
Load capacity	30	60	both inadequate for specified full payload and position afforded.
Roll and pitch	60	90	
Maintenance (on test)	80	70	frequency of attention (October model of Vehicle B)
Surmounting obstacles to mobility (driver in vehicle)	70	80	slight difference; "A" overturns, is easier to immobilize
Slippage	90	70	vegetation and wet condition in belt mechanism
Involuntary deceleration	80	70	best when driver not sensitive
Maintaining minimum speed	60	80	reversed when driver outside
Maximum speed	100	75	25 per cent differential but "A" only 100 lb. payload as convenient maximum
Available power	90	90	"B" better in "D" Class (weight + power)
Driver comfort	40	90	"A" is poor; driver must shift weight and jump out; also hot seat
Load space	40	80	
Turning radius	90	70	"A" very good, but might overturn
Reversing (if man-handling allowed)	20	90	"A" must be man-handled
Acceleration	100	100	both excellent
Seaworthiness	80	90	
Speeds in A	80	100	
B	90	80	
C	10	10	"nil"
D	50	50	
E	90	80	

Activity or Characteristic	Vehicle A	Vehicle B	Remarks
Speeds in water	70	70	
short trails (inorganic)	90	80	slight differential
long course	60	90	highly significant
Maneuverability and obstacles (mineral terrain)	90	80	when driver dismounted
	70	90	when driver mounted
Running time on course	75	100	"B" 25 per cent better
Vulnerability of machine	90	80	
Average relative performance index	68.8	79.1	



Relative Climbing Ability of Vehicle A (solid line) and Vehicle B (broken line)

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APPENDIX 1

Characteristics and Data

VEHICLE 'A'

Vehicle 'A' is a small, highly unorthodox, amphibious vehicle (Figs. 1 and 2). It carries two men and their equipment (400 lb.) and has a one-piece fiberglass body with six small wheels. The three wheels on each side are driven by chain-saw-type motors through Varidrive V-belts and sprocket and chain reduction stages. Steering is by differential throttle, or brake controls mounted on a driver's T-handle, or both.

The vehicle has extraordinary mobility due to its closely pitched low-pressure (1 psi) tires and high specific power, and (by virtue of its empty weight of 260 lb.) it can go almost anywhere that two men can go and some places where they can not, such as across lakes and swamps and deep tree-line snow.

A special girderized track of aluminum alloy is being developed for this vehicle to enhance its mobility under some conditions.

DIMENSIONS

Length	76 in.	
Width	51 in.	
Height	35 1/2 in.	
Wheel base	43 1/2 in.	
Track-front, center, and rear	40 in.	
Min. ground clearance with full load	6 1/2 in.	
Approach angle	55°	
Departure angle	89°	
Gradeability	60°	
Tipping angle — side slope w/full load	62°	
Height of c. of g., bare vehicle	13 in.	
Min. turning radius over outside wheel	11 ft. on land	12 ft. in water
Freeboard (when swimming)	16 in.	

WEIGHTS

Curb weight	278 lb.
Personnel, Payload allowance	400 lb.
Gross vehicle weight	678 lb.
Max. speed	15 m.p.h.
Min. speed	2.5 m.p.h.
Max. speed in water	3 to 5 m.p.h.

ENGINES

Make	Power products AH58 modified to specification 1370 and 1371	
Type	Gasoline, 2 cycle, 1 cylinder	
BHP each	4 BHP at 3,500 r.p.m.	5.7 BHP at 6,000 r.p.m.
Torque	6.0 lb. ft. at 3,500 r.p.m.	5.0 lb. ft. at 6,000 r.p.m.
Fuel tank capacity	6.3 gal. (Imp.)	
Fuel consumption	0.9 lb./BHP/hr.	

TRANSMISSION

Clutch	Mercury
Type	Centrifugal
Engagement speed	2,300 r.p.m.
Reduction	Clutch sheave: primary — 2.65: 6.25
	Primary: varispeed — 2.64: 7.90
	Varispeed: running gear — 10: 66
Final ratio	46.5:1

WATER PROPULSION

By centrifugal pump mounted co-axially with engine crankshaft and jet.

TIRES

Type	25° lug
Pressure (all uses)	0.5 to 1.0 psi.
Ply rating	none
Diameter	19 1/4 in.
Width	11 in. (optional)

STEERING

By differential throttle control and brakes.

VEHICLE 'B' (Figs. 3 and 4)

This is a small amphibious vehicle that uses a method of locomotion similar to that of the Borg-Warner "Airoll" vehicle. There are, however, several important design differences which, in our view, make it more suitable for small vehicles. It is heavier than the mechanically simpler vehicle 'A', and has a fundamental disadvantage due to the cyclic movement of the center of pressure relative to the center of gravity, which induces a pitching oscillation. However, the prototype vehicle has exhibited exceptional obstacle climbing ability, and should be well suited to traversing paddy-fields and to difficult water exit problems.

DIMENSIONS

Length	96 in.
Width	64 in.
Height to sill	39 in.
Tires	12 in. W x 16 in. D
Tire pressure	2 to 3 psi

WEIGHTS

Curb weight	750 lb.
Payload (incl. driver)	500 to 600 lb.

ENGINE

OMC 4 cycle or Villiers 2 cycle of ca. 9 HP.

TRANSMISSION

Duramatic plus Varidrive and chain reductions.

NOTE: Detailed information cannot be released at this time, owing to patent applications pending.

RAT (CL-70)

Characteristics and Data

The RAT is a small, amphibious, articulated, tracked vehicle with an aluminum alloy body. Steering is accomplished by warping the rear unit about the axis of articulation by means of cable and pulley mechanisms between the front and rear units.

The RAT has been tested by OATRU in some categories of muskeg, and has had some success over other vehicles in difficult conditions, because of its bellyless configuration and low ground pressure (3 psi with full load).

DIMENSIONS

Length	157 in.
Width	48 in.
Height (basic)	36 in.
Height (over windshield)	61 in.
Mean turning radius	11 ft.

WEIGHTS

Vehicle weight (empty)	1,500 lb.
Gross vehicle weight	2,500 lb.
Payload (carried)	1,000 lb.
Payload (towed)	1,000 lb.

ENGINE

Model	Volkswagen	
Type	4 cylinder, air-cooled	
Horsepower	30 BHP at 3,400 r.p.m.	(36 h.p. SAE rating)

TRANSMISSION

Clutch	single plate, dry disc
Gear-box	4 forward, 1 reverse

TIRE PRESSURES

Normal	45 psi
Rough surfaces	80 psi

WATER BUFFALO

Characteristics and Data

DIMENSIONS

Length	16 ft.	
Width	12 ft.	
Height	8 ft.	
Track width	48 in.	
Ground pressure	3.1 psi	
Approach angle	60°	
Cable	200 yd. length	3/4 in. diameter

WEIGHT

Vehicle weight	33,000 lb.

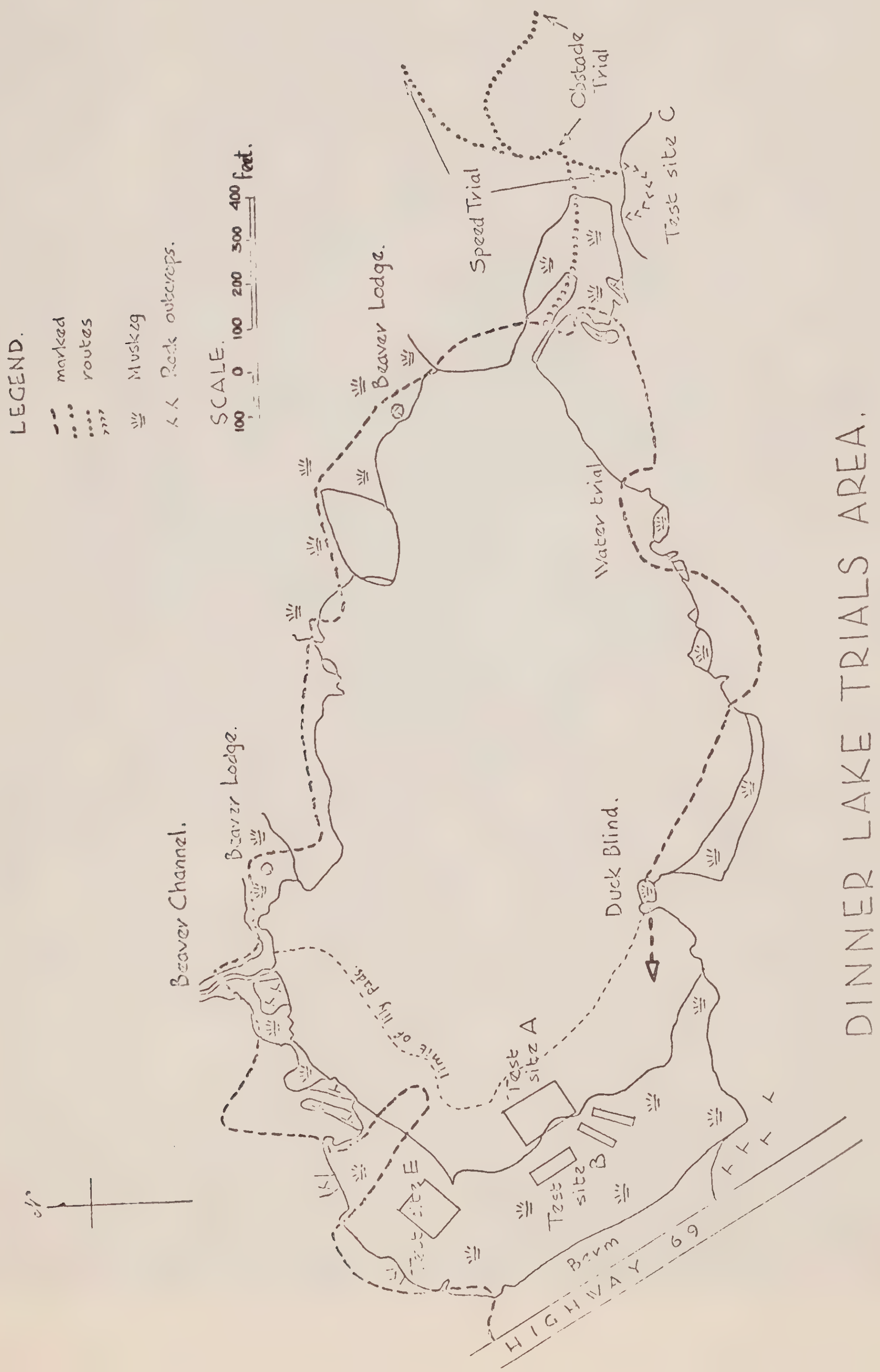
ENGINE

Albion	4 cyl. Diesel	65 BHP at 1,800 r.p.m.
Gear box	5 forward, 1 reverse	
Steering	2 brakes and clutches	

Winch synchronized in every gear.

APPENDIX 2

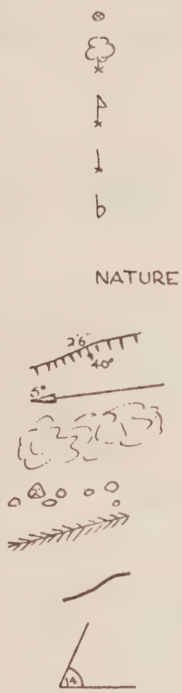
Sketch map Dinner Lake



Appendix 2. Aerial Photo of Dinner Lake Trials Area

LEGEND

TRAIL MARKERS



- painted stone
- tree with blaze and cloth marker
- stake with cloth marker
- tree stump with cloth marker
- buoy in open water

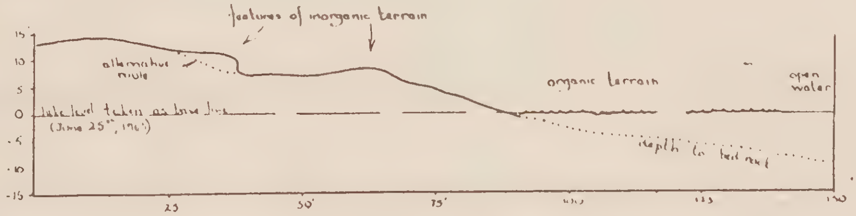
NATURE OF THE TERRAIN

- rock step with maximum gradient and maximum height indicated
- average maximum gradient over section of trail covered by arrow
- shrubs or trees - as indicated
- boulders - with maximum diameter indicated
- ridge
- boundary between mineral terrain, organic terrain, and open water
- location of photograph with number for identification

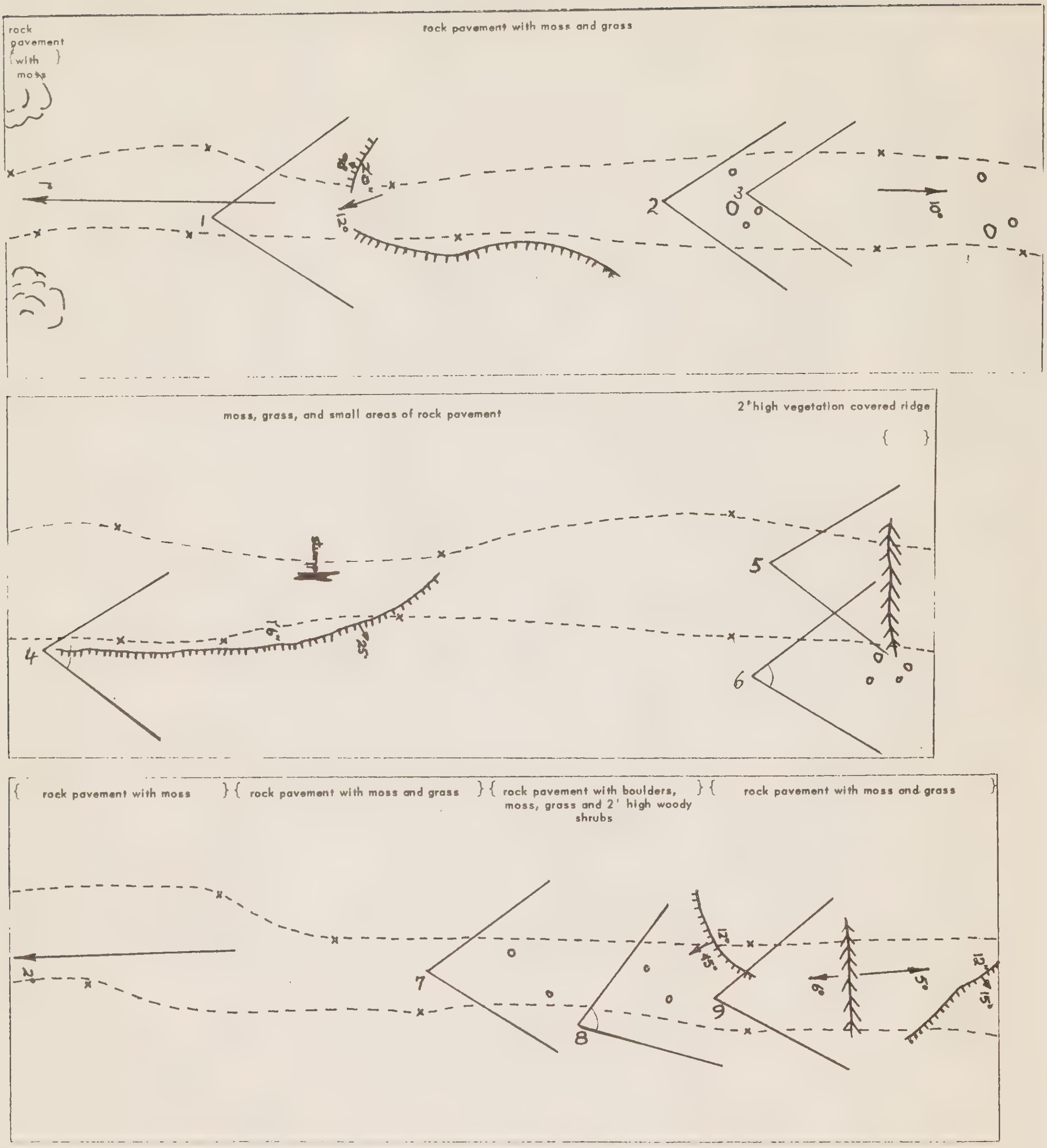
SCALE

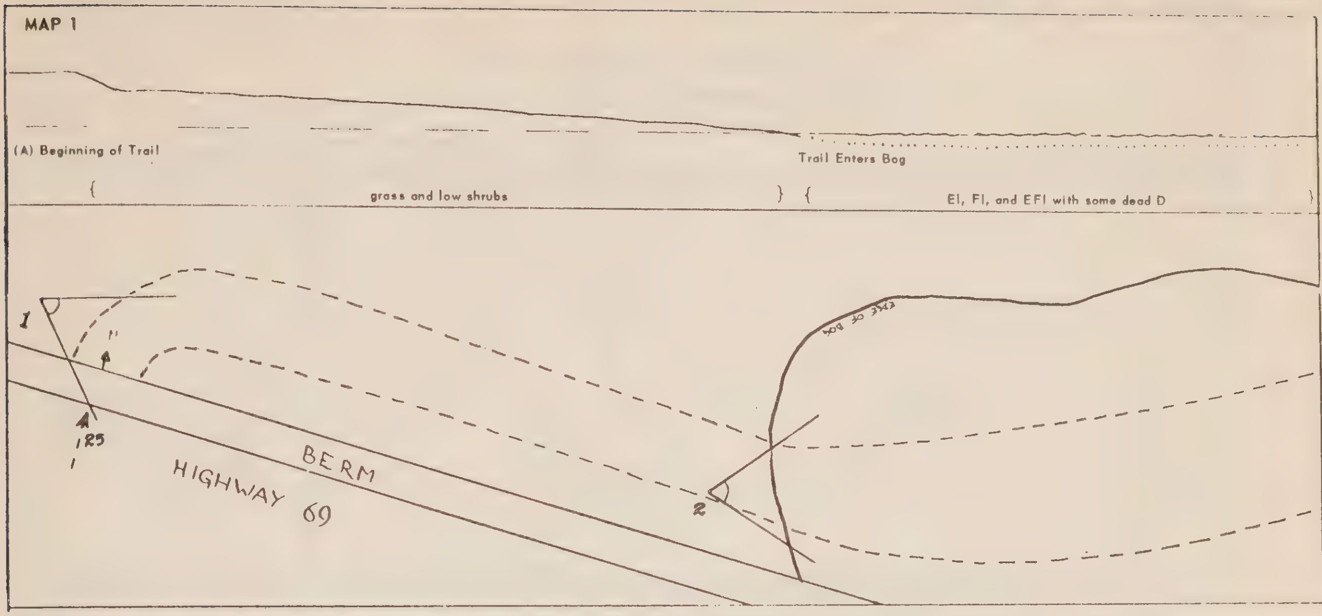
scale for maps and profiles : 1 inch represents 17½ feet

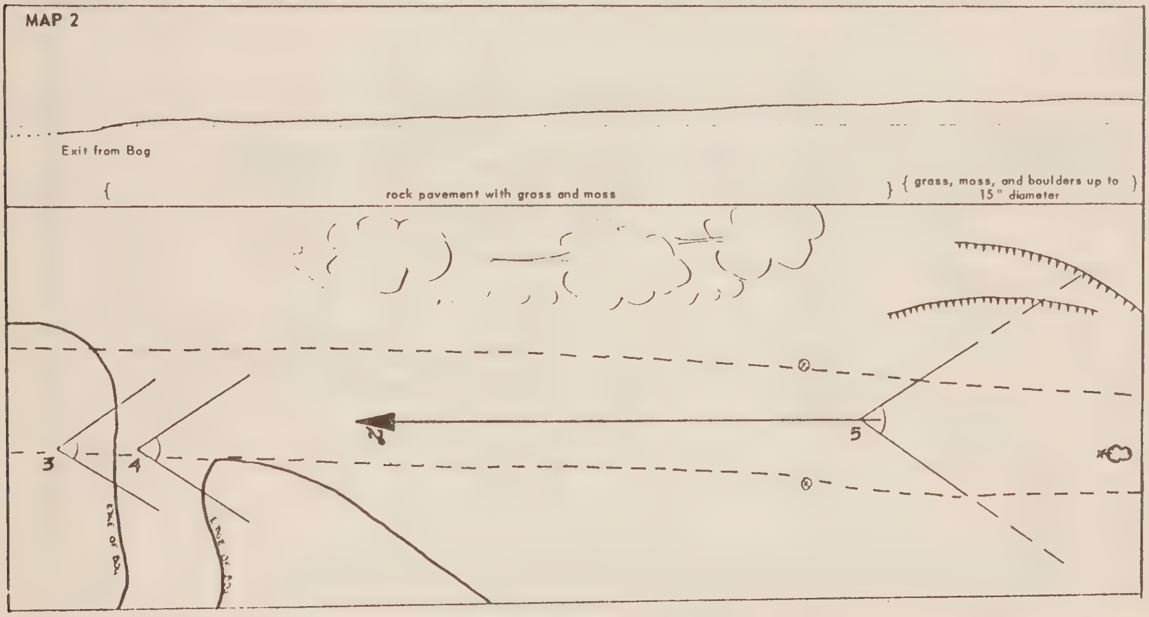
LEGEND FOR PROFILES

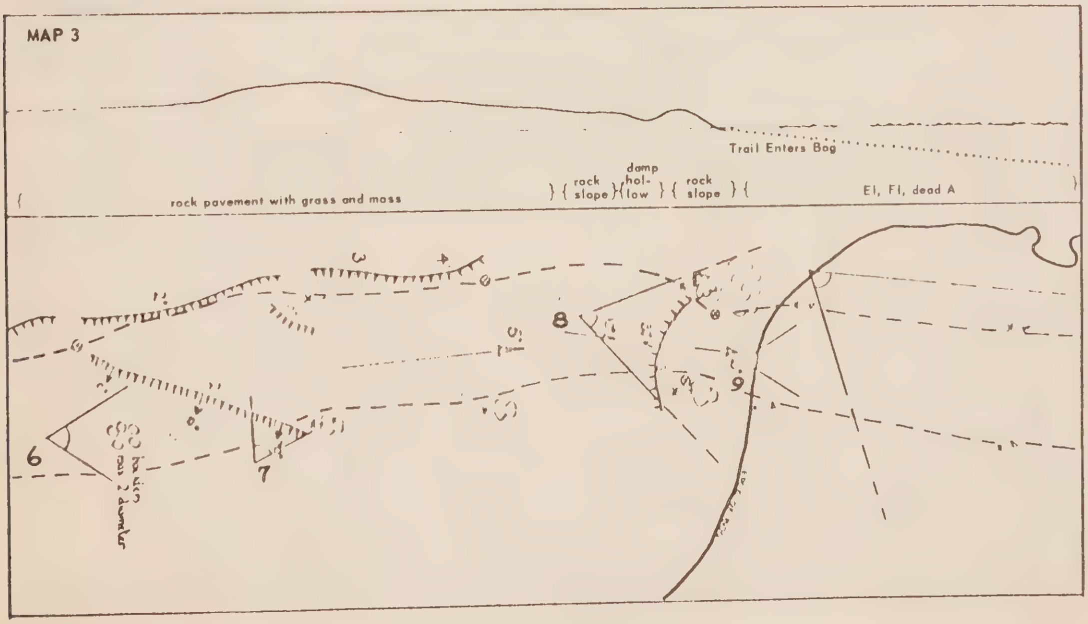


SHORT INORGANIC TRAIL

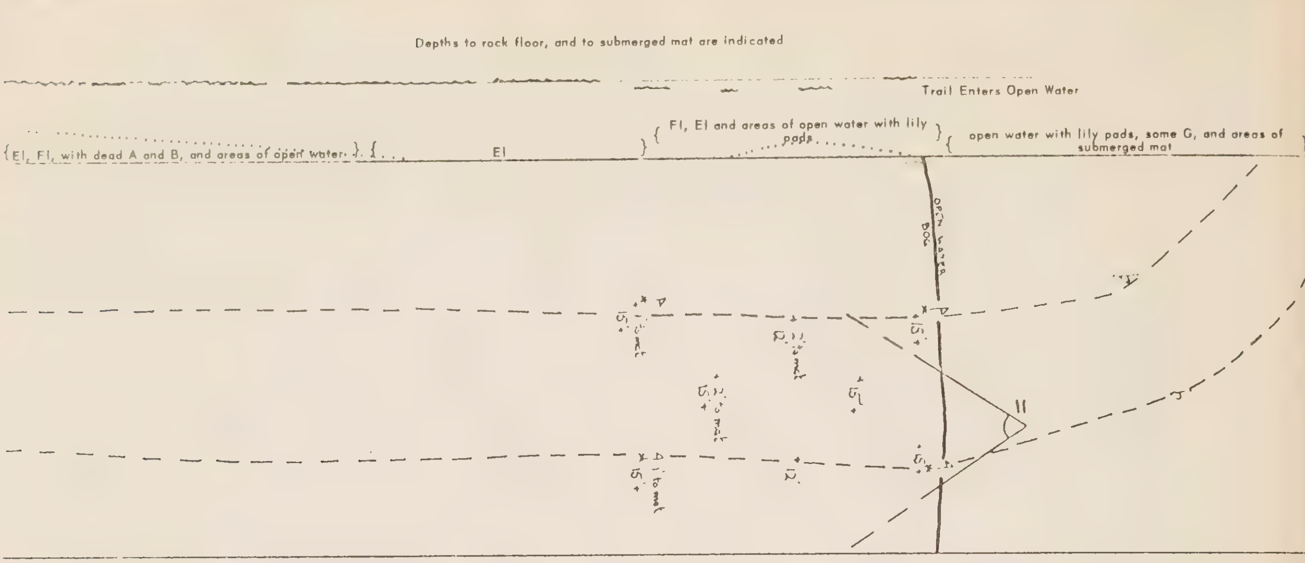



MAP 1
(A) Beginning of Trail
Trail Enters Bog
grass and low shrubs
El, Fl, and EFl with some dead D
1
BERM
HIGHWAY 69
2

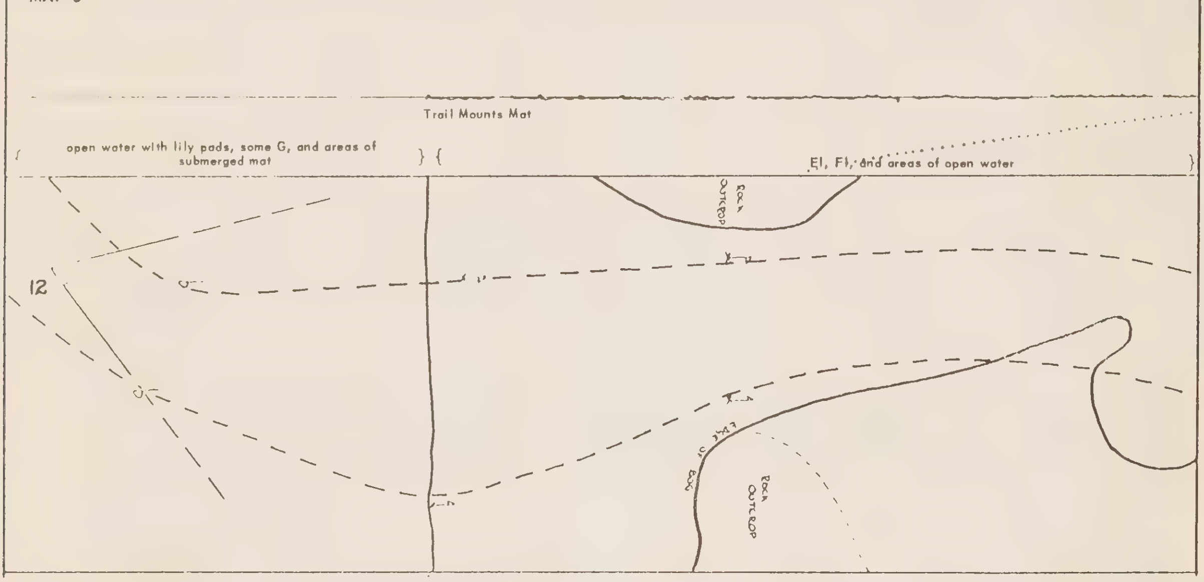

MAP 2
Exit from Bog
rock pavement with grass and moss
grass, moss, and boulders up to 15" diameter
3
4
5


MAP 3
Trail Enters Bog
rock pavement with grass and moss
rock slope
damp hollow
rock slope
El, Fl, dead A
6
7
8
9

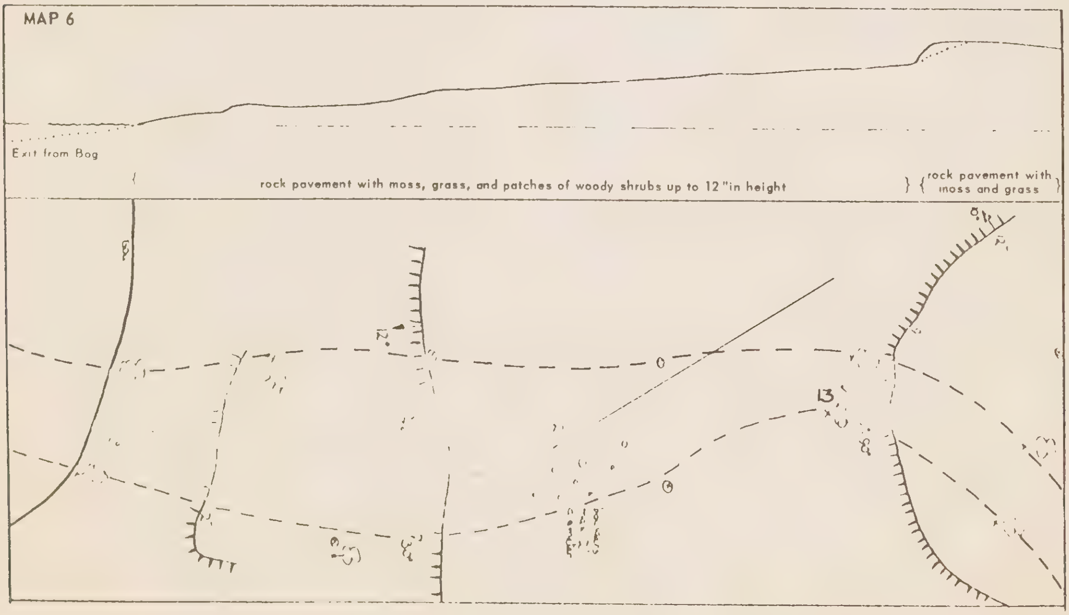
MAP 4



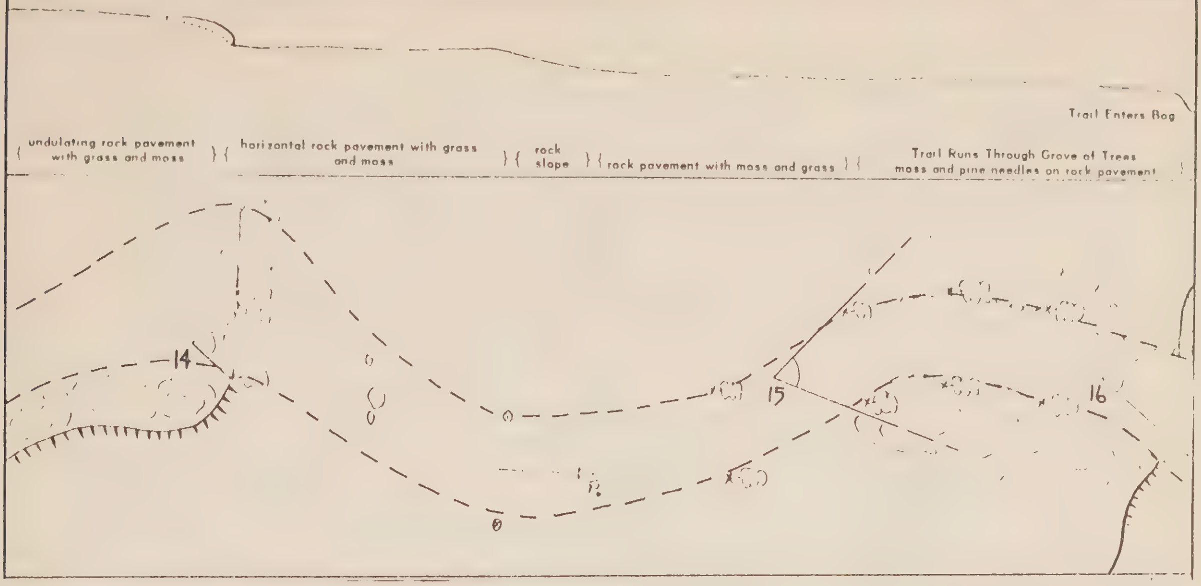
MAP 5



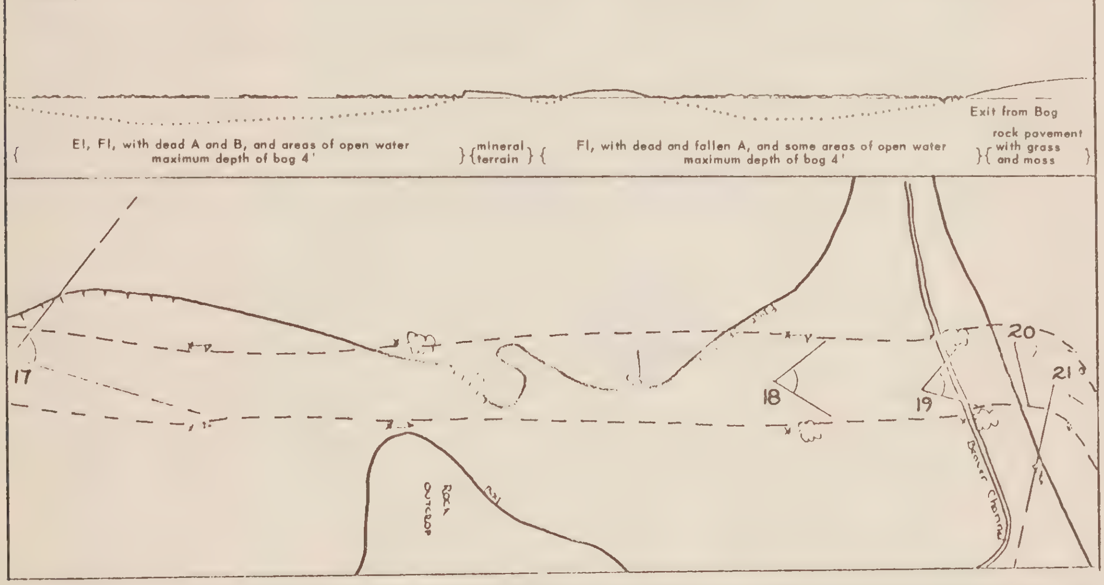
MAP 6



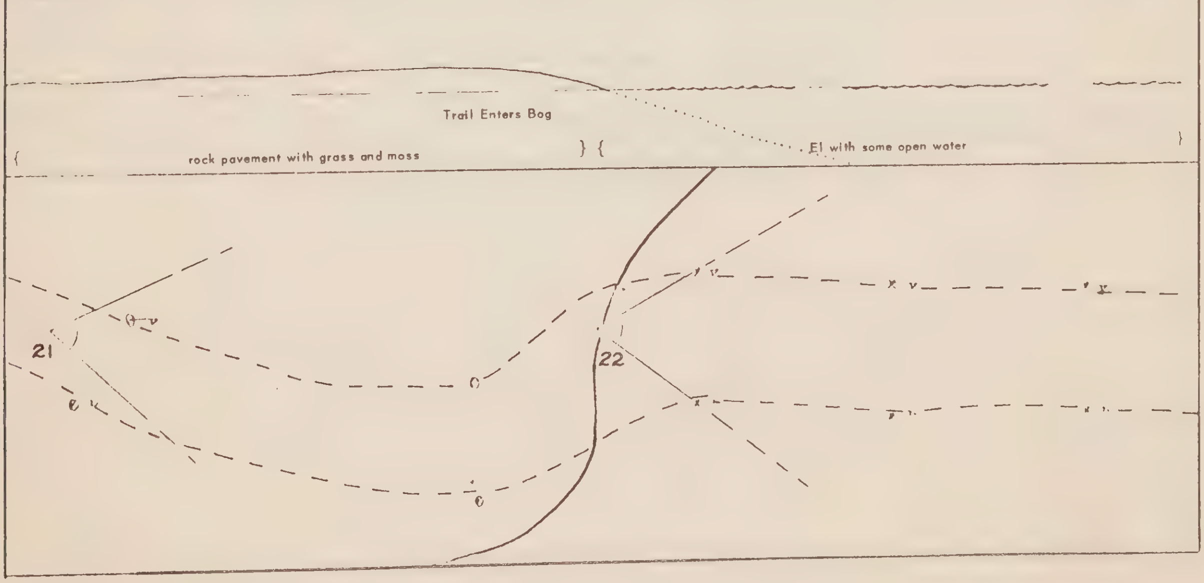
MAP 7



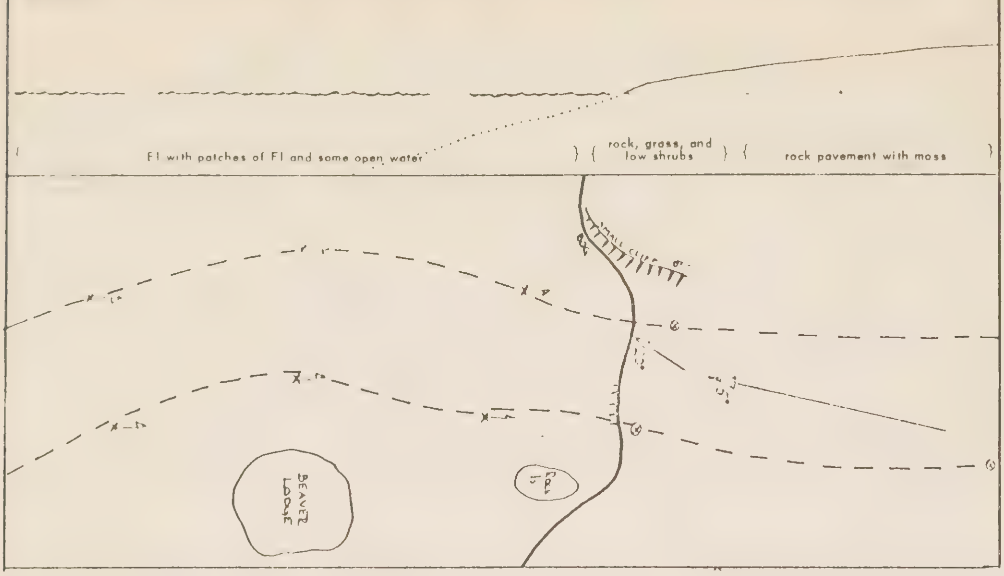
MAP 8



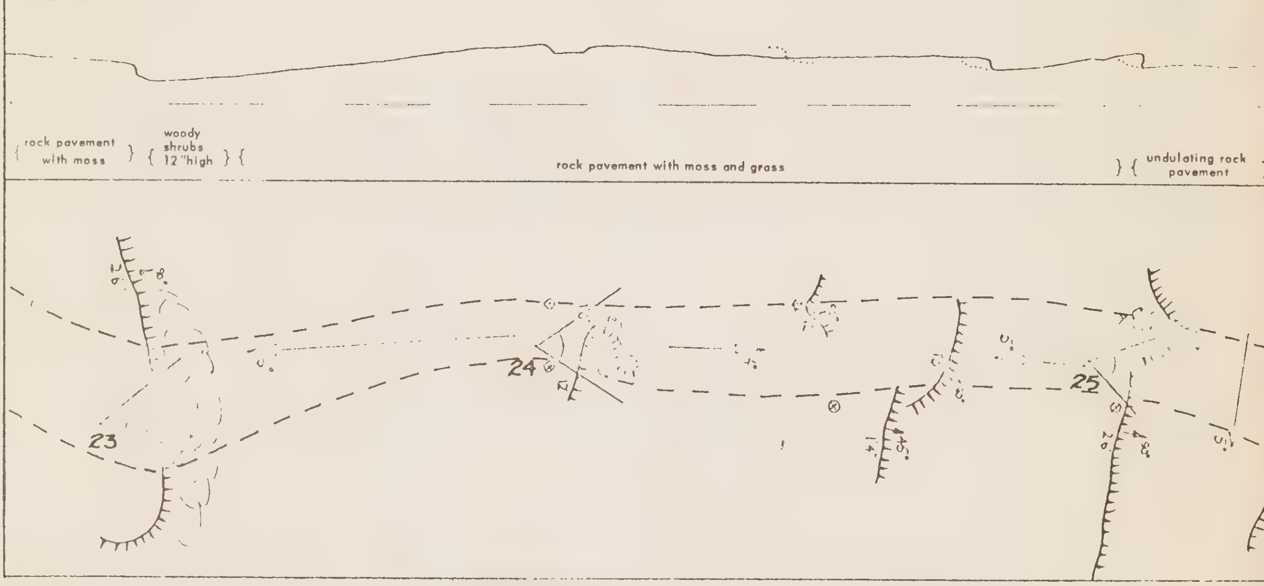
MAP 9



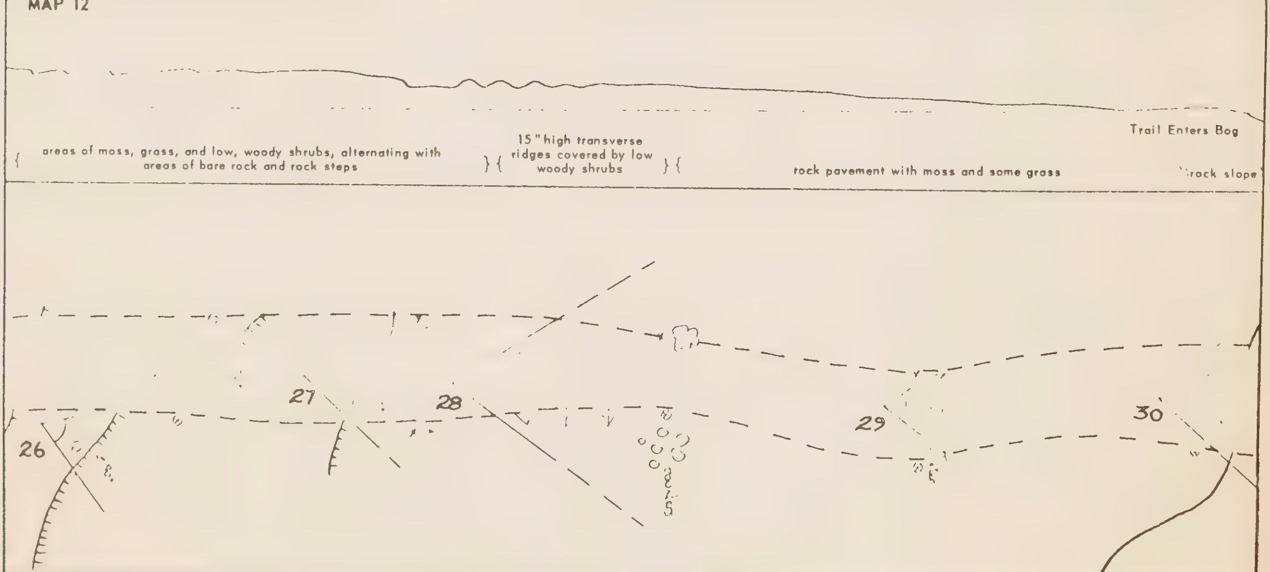
MAP 10



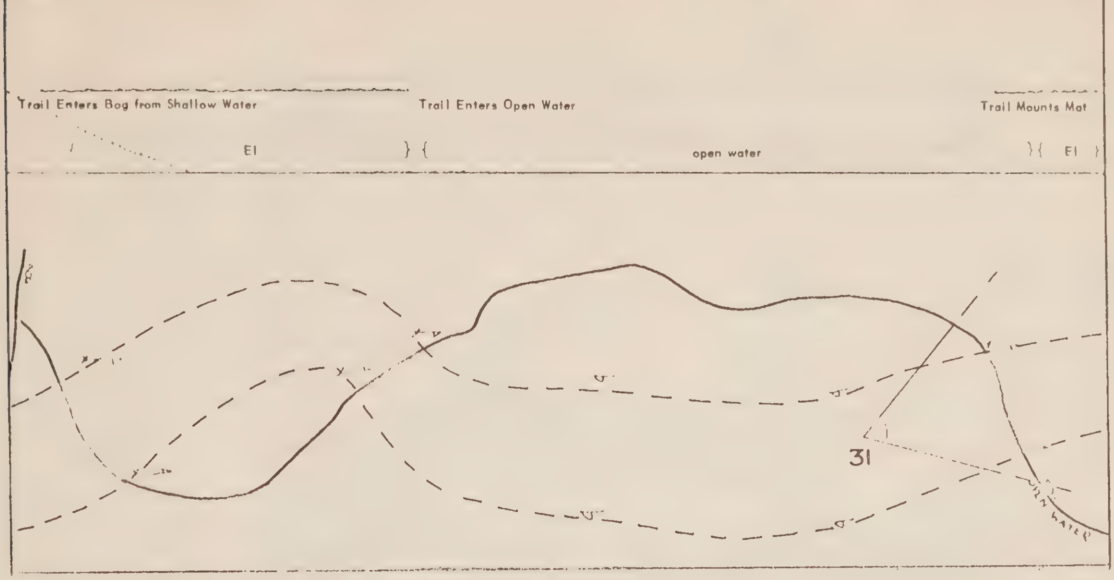
MAP 11



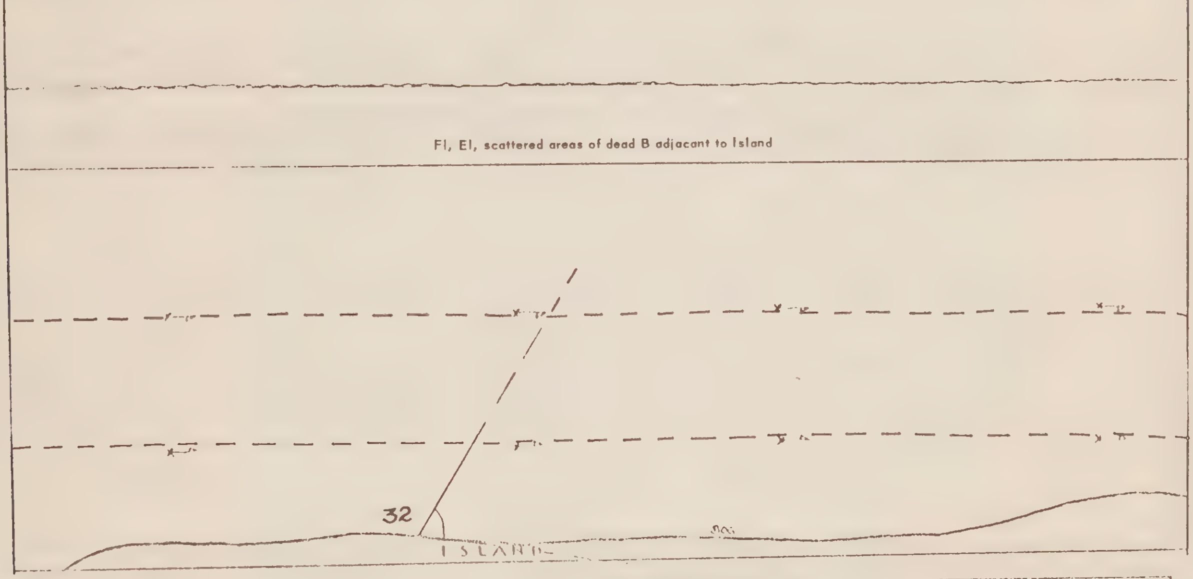
MAP 12



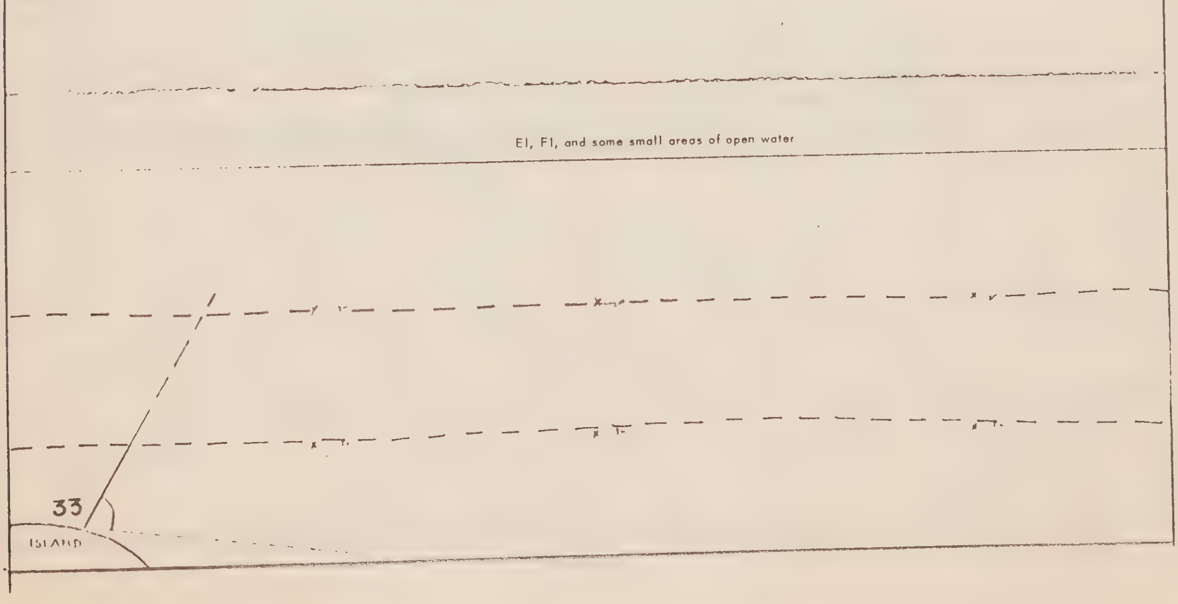
MAP 13

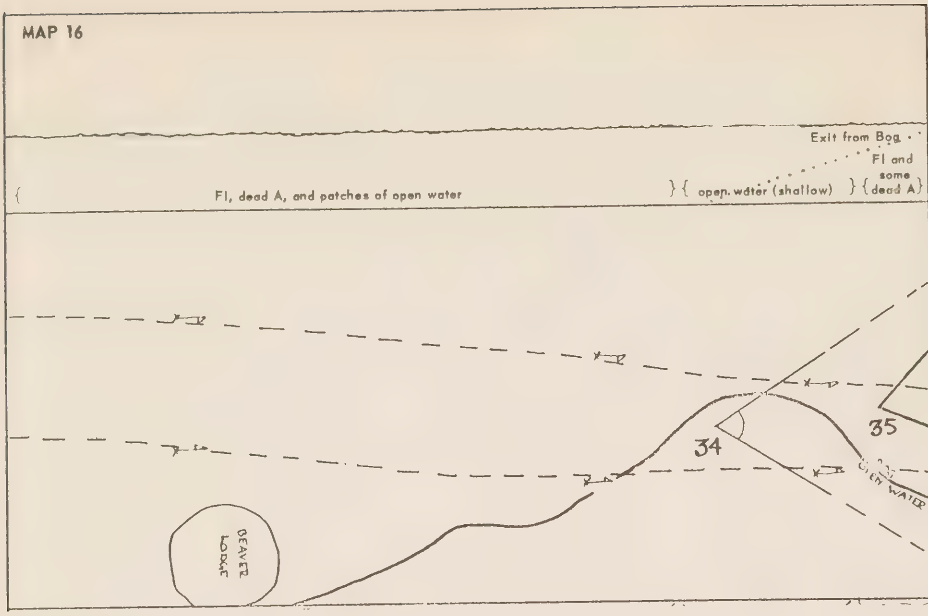


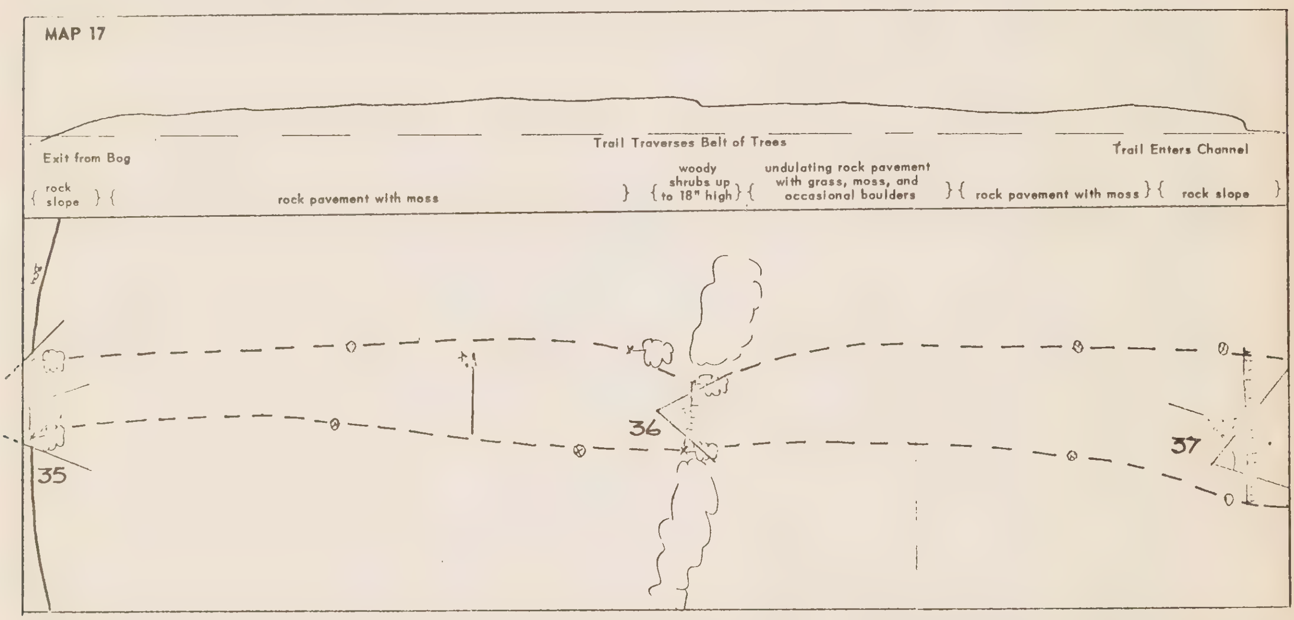
MAP 14

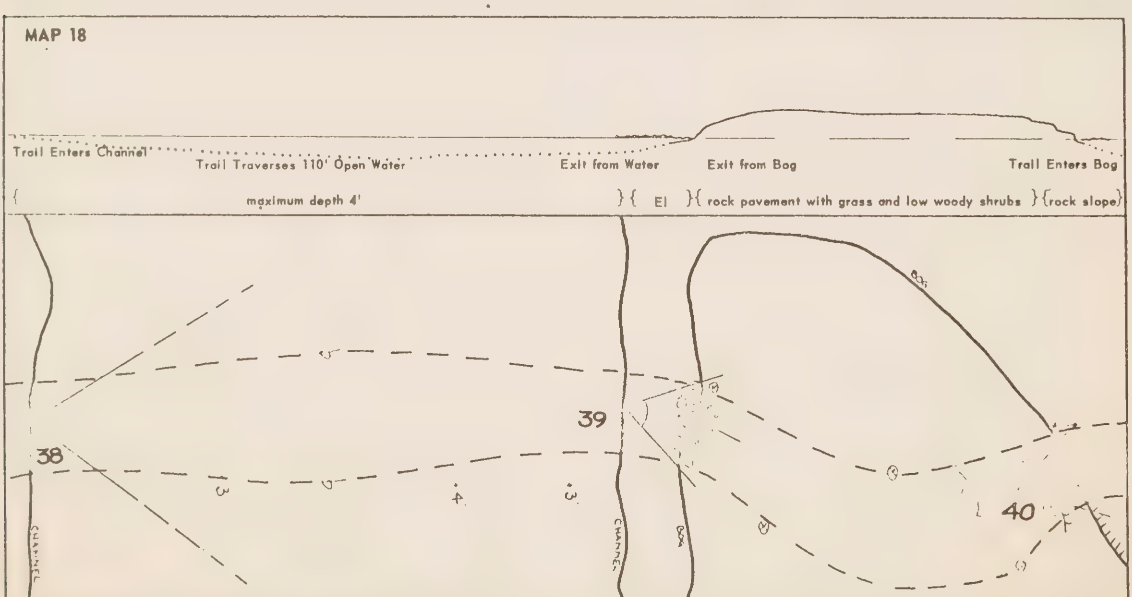


MAP 15

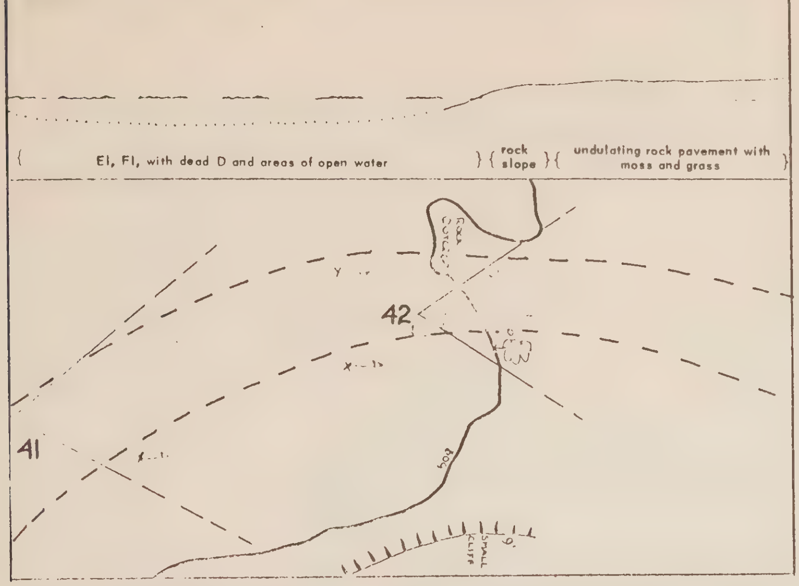



MAP 16
Exit from Bog
Fl and some dead A
Fl, dead A, and patches of open water
open water (shallow)
34
35
OPEN WATER
BEAVER LODGE

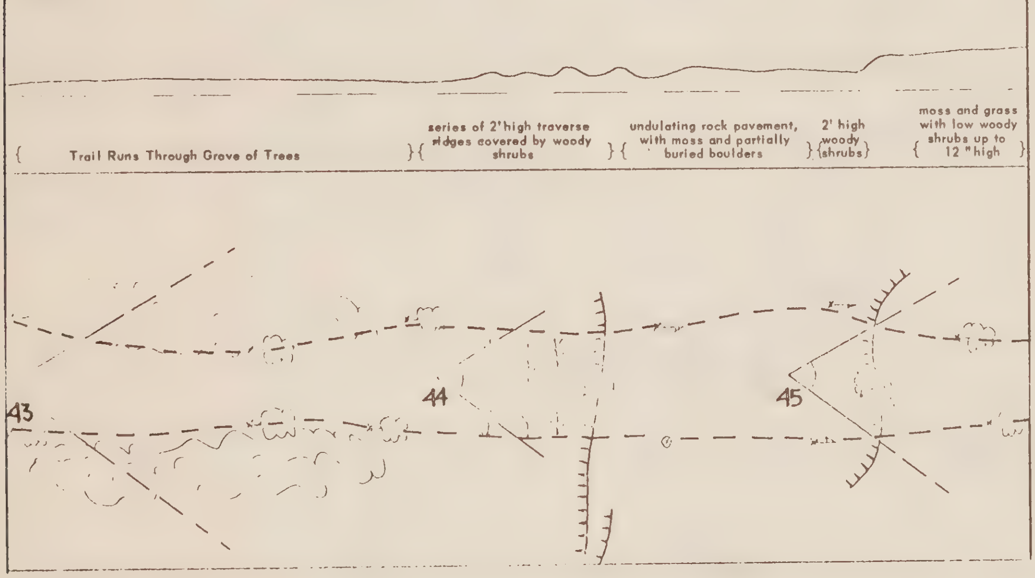

MAP 17
Trail Traverses Belt of Trees
Exit from Bog
Trail Enters Channel
rock slope
rock pavement with moss
woody shrubs up to 18" high
undulating rock pavement with grass, moss, and occasional boulders
rock pavement with moss
rock slope
36
35
37


MAP 18
Trail Enters Channel
Trail Traverses 110' Open Water
Exit from Water
Exit from Bog
Trail Enters Bog
maximum depth 4'
El
rock pavement with grass and low woody shrubs
rock slope
38
39
40
CHANNEL
CHANNEL

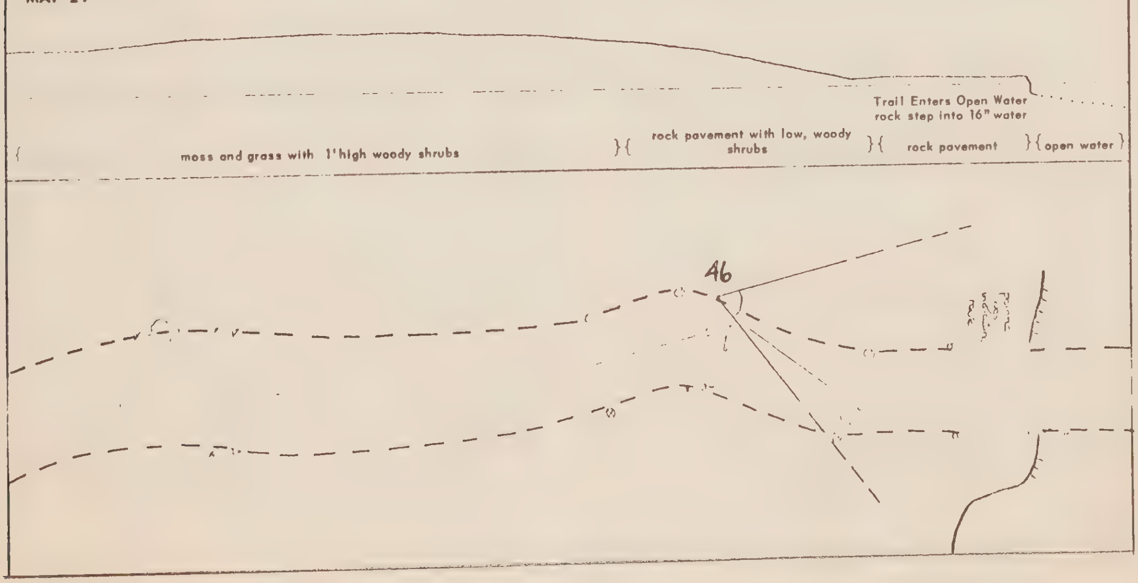
MAP 19



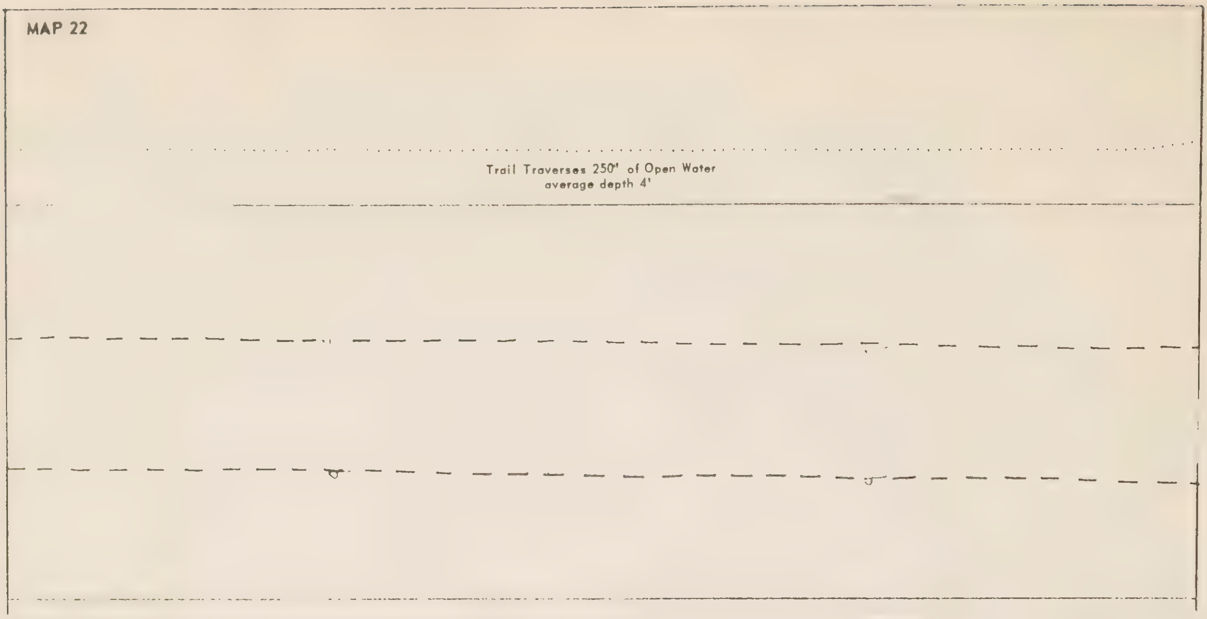
MAP 20



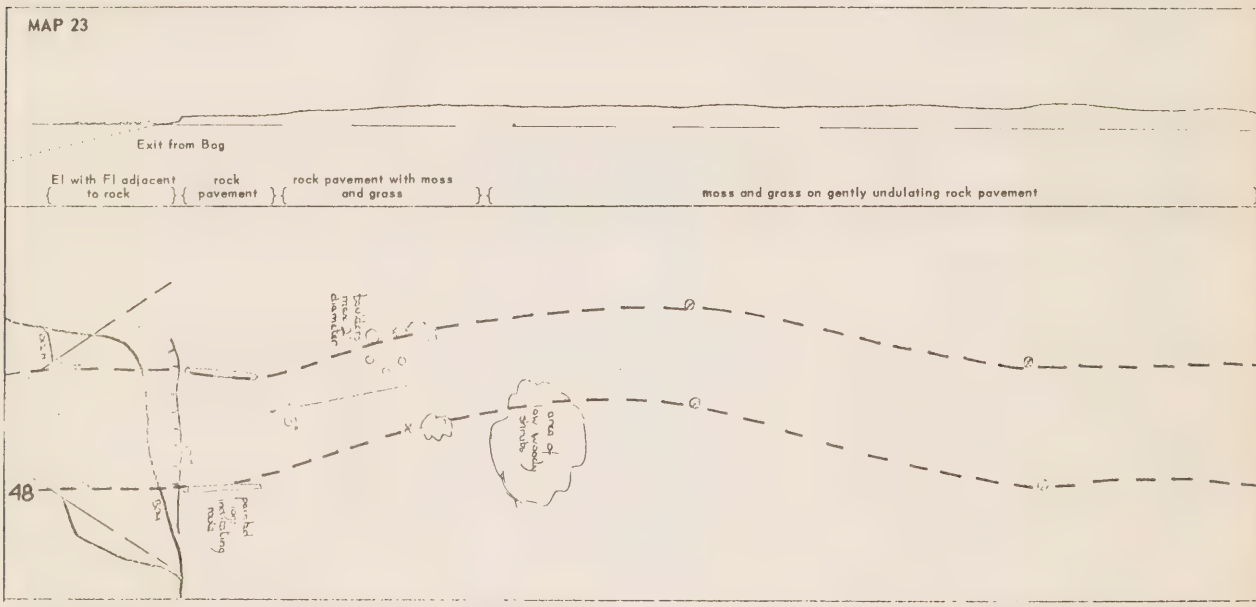
MAP 21



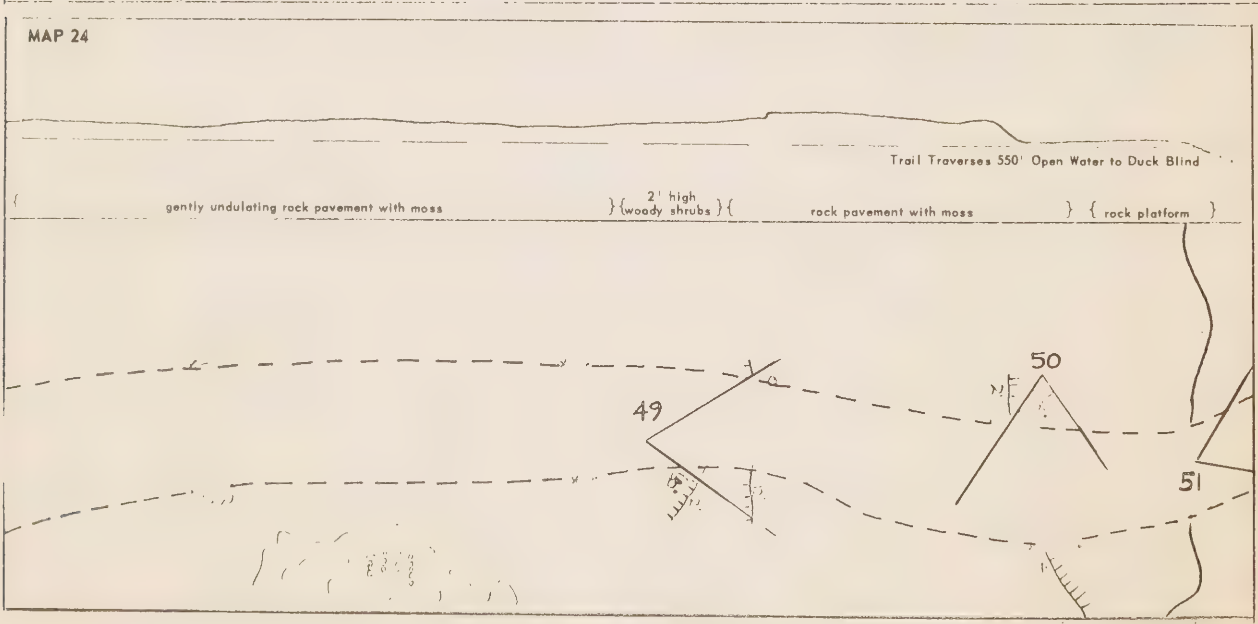
MAP 22



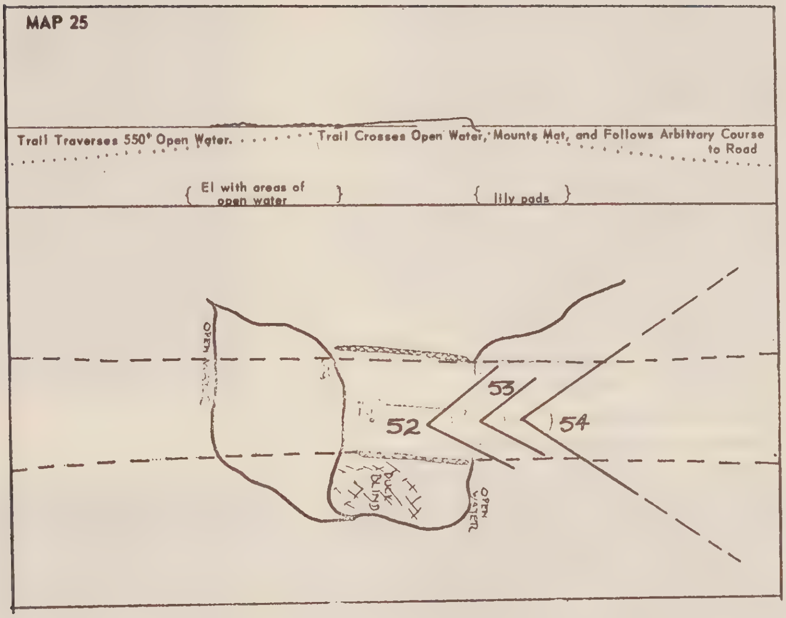
MAP 23



MAP 24



MAP 25


Trail Traverses 550' Open Water.
Trail Crosses Open Water, Mounts Mat, and Follows Arbitrary Course to Road
El with areas of open water
lily pads
OPEN WATER
52
53
54
DUCK BLIND
OPEN WATER

INDEX TO PHOTOGRAPHS

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5

Fig. 6

Fig. 7

Fig. 8

Fig. 9.

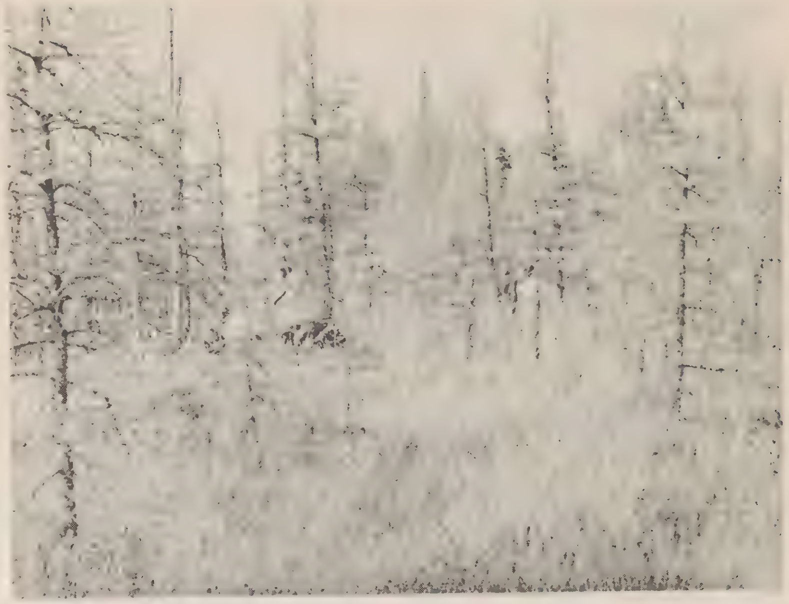


Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 17.

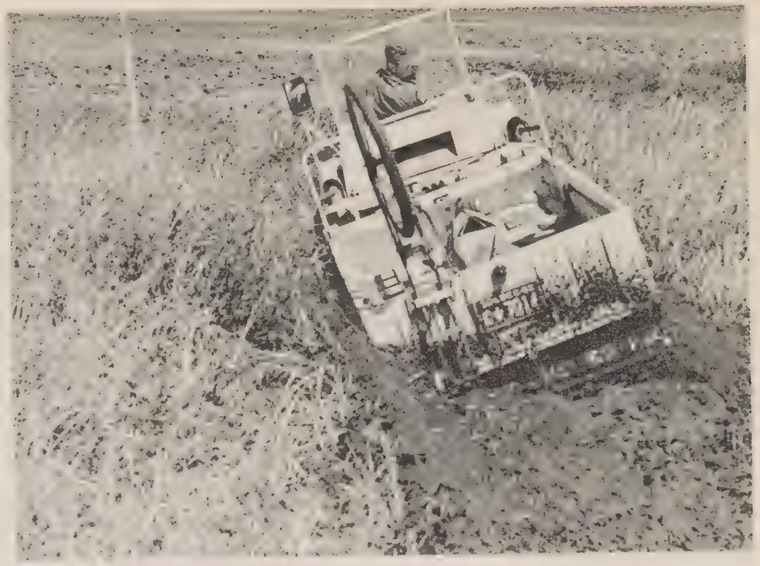


Fig. 18.

Fig. 19.

Fig. 20.


Fig. 21.


Fig. 22.


Fig. 23.


Fig. 24.

Fig. 25.

Fig. 26.

Fig. 27.

Fig. 28.

Fig. 29.

Fig. 30.

Fig. 31.

Fig. 32.

Fig. 33.

Fig. 34.

Fig. 35.

Fig. 36.

Fig. 37.

Fig. 38.

APPENDIX 3

Cone Penetrometer Values

Test Site A — None obtained. However, fluid amorphous granular peat, such as present at this site, would yield values below 20.

Test Site B

	VEHICLE A						VEHICLE B		RAT	
Depth Inches	with tracks			without tracks					Average of 6 sites	
	0 Pass	20 Pass	39 Pass	0 Pass	20 Pass	50 Pass	0 Pass	16 Pass	0 Pass	Final Pass
0	11.5	8.5	4.0	13.0	8.0	1.0	10.5	5.0	24.5	36.0
3	21.0	21.5	17.0	29.5	26.5	11.5	19.0	10.5	35.0	44.0
6	25.0	29.0	23.0	33.0	25.5	28.0	26.0	16.5	37.0	41.0
9	30.0	30.0	27.0	24.0	22.5	26.5	29.5	22.5	40.0	43.0
12	37.0	35.0	29.0	27.5	27.5	27.5	32.0	25.0	42.0	46.0
15	33.5	31.0	30.0	25.5	22.0	20.5	36.5	33.5		
18	35.0	31.5	26.5	31.0	24.5	25.0	33.5	29.5	48.5	50.0
24	29.0	25.0	26.0	34.0	31.0	30.5	30.0	28.5	50	51.0
30	28.0	23.0	18.5	23.0	21.0	25.0	28.0	27.0		
36	33.0	21.5	18.0	22.0	21.0	19.5	25.0	18.0	52	52.5
48	29.5	22.0	18.5	21.5	18.5	20.0	27.0	19.5		
60	30.0	22.0	20.5	22.0	19.5	20.0	29.0	22.0		
72	30.0	23.5	22.5	24.5	22.0	19.5	27.5	23.0		

Test Site C — None obtained. Surface obstructions judged to be main factor in mobility comparison. Cone index values may vary between 10 and 100.

Test Site D — None obtained. As above. Cone index values may vary between 10 and 300.

Test Site E — None obtained. Original site not used. Alternate site chosen for microtopographic characteristics judged to be a factor in mobility comparison. Cone index values may vary between 10 and 200.